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LOOD PLAIN MANAGEMENT STUDY

CLAM RIVER WEXFORD COUNTY, MICHIGAN

JULY 1987



prepared by:

**U.S. Department of Agriculture
Soil Conservation Service
East Lansing, Michigan**

in cooperation with:

**Michigan Department of Natural Resources
Cherry Grove, Clam Lake, Haring and Selma Townships, City of Cadillac and Wexford County
Wexford County Soil Conservation District**

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FOREWORD

This report defines the flood characteristics of the Clam River, Lake Cadillac, Lake Mitchell and Pleasant Lake located in Wexford County, Michigan. Development exists within the flood plain and can be expected to increase in the future.

This cooperative report was prepared for the guidance of local officials in planning the use and regulation of the flood plain. Four potential floods are used to represent the degrees of major flooding that may occur in the future. These floods, the 10-year, 50-year, 100-year and 500-year, are defined in the report and should be given appropriate consideration in future planning for safety of development in the flood plain. Over 6.6 miles of high water profiles along the Clam River show the expected flood elevations and water depths relative to the stream bed and flood plain. The 100-year and 500-year potential floods, in addition to flood prone areas around Lake Cadillac and Lake Mitchell, are further defined by flood hazard area photomaps that show the approximate areas that would be flooded.

Flood hazard area photomaps and high water profiles are based on existing conditions of the basin, stream and valley when the report was prepared.

Information in this report does not imply any federal authority to zone or regulate the use of flood plains; this is a state and local responsibility. This report provides a suitable basis for adoption of land use controls to guide flood plain development, thereby preventing intensification of flood losses.

Technical documentation for this study is on file with the Soil Conservation Service-USDA, 1405 South Harrison Road, East Lansing, Michigan 48823 (telephone 517-337-6612) and the Land and Water Management Division, Michigan Department of Natural Resources, Mason Building, P.O. Box 30028, Lansing, Michigan 48909.

Assistance and cooperation of the U.S. Geological Survey; Wexford County Soil Conservation District; city of Cadillac; Cherry Grove, Clam Lake, Haring and Selma Townships; and the Michigan Department of Natural Resources in the preparation of this report is greatly appreciated.

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FLOOD PLAIN MANAGEMENT STUDY

CLAM RIVER

WEXFORD COUNTY, MICHIGAN

INTRODUCTION

The flood plains of rivers, lakes and streams have been formed by nature to provide for the conveyance of flood flows resulting from large amounts of snowmelt and rainfall. Floods are acts of nature which cannot be wholly prevented by man. Therefore, the long-term solution to reducing flood damage and loss of life is to keep the flood plain void of development which could be damaged or which could obstruct the conveyance of flood waters. There are three basic actions which can be used to assure that flood plain areas are kept open:

1. Provide public information to make lending institutions and prospective property buyers aware of the flood hazards.
2. Initiate flood plain regulations to prevent the development of the flood plain in a manner which would be hazardous during floods.
3. Acquisition of flood prone areas for use as parks, open space, wildlife habitat and other public uses.

Potential users of the flood plain should base their decisions upon the advantages and disadvantages of such a location. Knowledge of flood hazards is not widespread and, consequently, the managers, potential users and occupants cannot always accurately assess the risks. In order for flood plain management to be effective in the planning, development and use of flood plains, it is necessary to:

1. Develop appropriate technical information and interpretations for use in flood plain management.
2. Provide technical services to managers of flood plain property for community, recreational, industrial and agricultural uses.
3. Improve basic technical knowledge about flood hazards.

Two Michigan state laws provide the Michigan Department of Natural Resources the responsibility and the authority to regulate all development in the flood plain areas.

Act 288, Public Acts of 1967, establishes minimum standards for subdividing land and for new development for residential purposes within flood plain areas. This act requires that preliminary plats be submitted to the Land and Water Management Division, Michigan Department of Natural Resources for review and determination of flood plain limits. Upon completion of review and establishment of the 100-year frequency flood plain limits, the preliminary plat may be approved and minimum building requirements specified.

Act 245, Public Acts of 1929 as amended by Act 167, Public Acts of 1968, requires that a permit be obtained from the Land and Water Management Division, Michigan Department of Natural Resources before filling or otherwise occupying the flood plain or altering any channel or watercourse in the state. The purpose of this control is to assure that the channels and the portion of the flood plain that are the floodways are not inhabited and are kept free and clear of interference or obstruction which will cause undue restriction of flood carrying capacities.

Requirements established by the Michigan Department of Natural Resources for occupation and development of flood plain areas under Acts 288 and 245 are intended to be minimum requirements only. The Department urges local units of government to adopt reasonable regulations which can be used to guide and control land use and development in flood hazard areas.

The Soil Conservation Service, United States Department of Agriculture carries out flood plain management studies under the authority of Section 6 of Public Law 83-566, in response to Recommendation 9(c), "Regulations of Land Use", of House Document No. 465, 89th Congress, 2nd Session and in compliance with Executive Order 11988, dated May 24, 1977. Flood plain management studies are carried out in accordance with Federal Level Recommendation 3 of "A Unified National Program for Flood Plain Management". The Soil Conservation Service and the Michigan Department of Natural Resources have agreed to carry out flood plain management studies in Michigan under provisions of the 1982 Joint Coordination Agreement. Priorities regarding location and extent of such studies in Michigan have been set in cooperation with the Michigan Department of Natural Resources.

The Wexford County Soil Conservation District; city of Cadillac; Cherry Grove, Clam Lake, Haring and Selma Townships; and the Michigan Department of Natural Resources (Sponsors) believed that a flood plain management study was needed for the Clam River, Lake Cadillac, Lake Mitchell and Pleasant Lake due to urbanization and the flooding problems that have already occurred. The Sponsors have determined that there is an increasing need to properly plan for the preservation and use of the flood plain in their urban and rural areas. They have indicated a need to develop technical information along the Clam River, Lake Cadillac, Lake Mitchell and Pleasant Lake to develop effective management programs.

The Sponsors have adopted resolutions indicating they intend to use the technical information from the flood plain management study as a basis for adopting zoning regulations, health and building codes, subdivision control regulations and such other regulations that may be needed to preserve the environmental quality of their natural resources, and to protect the health, safety, welfare and well-being of the citizens of their communities.

A request for a flood plain management study was made by the Sponsors and a plan of work, dated April 1985, was agreed to by the Sponsors, along with the Soil Conservation Service. Financial contributions for this study were made by the Sponsors and the Soil Conservation Service. The Wexford County Soil Conservation District will assist the other Sponsors with public information dissemination.

The Sponsors provided money for aerial photography for flood plain delineation uses and for watershed modeling purposes. They also furnished assistance to the Soil Conservation Service in gathering basic data. In addition, they also provided input to identify and select appropriate flood plain management alternatives.

The Land and Water Management Division, Michigan Department of Natural Resources provided coordination services with respect to study area discharges and hydraulics. They reviewed the technical aspects of the study and concurred with study results, as applicable, to implement various state statutes through the Federal Flood Insurance Program.

Natural flood plain values were obtained by Soil Conservation Service field people. Aerial photos and field checks were used to identify and delineate wetland areas. Topographic maps, planning commission data and communications with government officials were used to determine land use and development trends. Soils information was obtained from the published soil survey report for Wexford County.

Historic and archaeological data were obtained from township and county historians. Fishery management information was obtained from Michigan Department of Natural Resources field people.

In addition to flood prone areas, two floods are delineated, the 100-year and the 500-year frequency events. These floods have an average occurrence of once in the number of years as indicated; e.g. the 100-year flood occurs once in 100 years on the average. The 100-year flood has a one percent chance of being equaled or exceeded in any given year. In addition to flood prone areas and the two floods delineated on the aerial photomaps, the 10-year and 50-year floods are also shown on the high water profiles. The flood plain management program enacted by local action is to be based on the technical results and recommendations of this report.

The Land and Water Management Division, Michigan Department of Natural Resources and the Soil Conservation Service-USDA will, upon request, provide technical assistance to federal, state and local agencies and organizations in the interpretation and use of the information developed in this study. For assistance contact:

Wexford County Soil Conservation District
3060 West 13th Street
Cadillac, Michigan 49601-9658
Telephone: (616) 775-7422

DESCRIPTION OF STUDY AREA

Watershed Area

The Clam River is located in northwestern lower Michigan, in southeastern Wexford County. It is located in the U.S. Geological Survey's State Hydrologic Unit 04060102. Its headwaters form around Lake Cadillac and Lake Mitchell. From there, the Clam River flows in a northeasterly direction through the city of Cadillac and leaves the county about two miles north of M-55. The Clam River drains to the east and south into the Muskegon River. Part of the drainage area starts at Pleasant Lake and eventually outlets into the Clam River.

The drainage area is approximately 100 square miles with land uses of commercial, residential, recreation, agriculture, forest and open space. About 70 percent of the area is in woodland and about 10 percent is in cultivated crops. There are numerous culverts and crossings along the Clam River. Some of these are restrictive and cause the flooding of buildings and roads. Any replacement of crossings should be evaluated to see what the effect would be on downstream flooding.

There are five soil associations in the drainage area. Forty-three percent of the area consists of the Rubicon-Montcalm-Graycalm association, which has nearly level to steep, somewhat excessively drained and well drained sandy soils on moraines, till plains and outwash plains. Seven percent is the Grayling-Graycalm association, which has nearly level to moderately steep, excessively drained and somewhat excessively drained sandy soils on outwash plains, till plains and low moraines. Twenty-one percent of the area is the Kalkaska association, which has nearly level to steep, somewhat excessively drained and well drained sandy soils on outwash plains, till plains and moraines. Twenty-one percent is the Tawas-Croswell-Lupton association, which has nearly level and undulating, very poorly drained mucky and sandy soils in bogs, depressions and drainageways on low flat and benches. About two percent of the area is the Nester-Kawkawlin-Manistee association, which has nearly level to steep, well drained and somewhat poorly drained loamy and sandy soils on till plains and moraines. Lakes account for the remaining six percent of the drainage area.

In winter, the average temperature is 19.1°F., and the average daily minimum temperature is 10.9°F. In summer, the average temperature is 64.4°F., and the average daily maximum temperature is 76.7°F.

The average annual temperature is 49°F. The average annual precipitation is 30.8 inches. Of this, 18.4 inches, or 60 percent, usually falls in April through September, which includes the growing season for most crops. The average annual snowfall is 71.2 inches.

Historically, much of the watershed has been used for lumbering. Logging operations are limited to pulpwood and a small amount of timber harvested for lumber. Recreation is also a major industry.

Study Area Flood Plain

Beginning at the east county line two miles north of M-55, the study area proceeds southwesterly through the city of Cadillac, Lake Mitchell and Lake Cadillac. Part of the study area is around Pleasant Lake. High water profiles and flood plain delineations were made in Wexford County along the Clam River, as well as around Lake Mitchell, Lake Cadillac and Pleasant Lake. In addition, flood prone areas were delineated around Lake Cadillac and Lake Mitchell. The study area is identified on Figure 1.



VICINITY MAP

Figure No. 1

STUDY AREA MAP CLAM RIVER FLOOD PLAIN MANAGEMENT STUDY WEXFORD COUNTY, MICHIGAN

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SOURCE:
1983 GENERAL HIGHWAY MAP AND
INFORMATION FROM SCS FIELD PERSONNEL
POLYCONIC PROJECTION.

Much of the study area flood plain is wetlands. Wetland types found on National Forest within the Lake Mitchell flood plain consist of lowland brush (Type 6 USDI-Fish and Wildlife Circular No. 39); sedges, leatherleaf meadows (Type 2A); shallow and deep marshes (Types 3 and 4); bogs (Type 8); and wooded swamps (Type 7 - both conifer and hardwood). Of these wetland types, shrub swamps, bogs and wooded swamps predominate the landscape. Lowland conifers in the area include white cedar, black spruce, white pine, tamarack and balsam fir. Lowland hardwoods in the area include red maple, black ash, elm, aspen, balsam poplar and basswood. Within these types, small pockets of aspen and red maple may be found on dry ridges, often with balsam fir understories. Up-land ground cover includes bunchberry, wintergreen and Lycopodium. Lowland ground cover consists of sedges, grasses, Juncus and Scirpus.

Mammals that frequent or live within the flood plain include muskrat, beaver, snowshoe hare, cottontail rabbit, red squirrel, otter, mink, weasels, skunk, red fox, deer and bear. Deer utilize much of the area as a winter deer yard because of the extensive lowland conifer types, including balsam fir on relatively dry sites. Bears probably find denning opportunities in the many wind-throws in wooded lowlands. Habitat for the above species is considered good.

Birds that require mature or old growth hardwoods and conifers are found in abundance in this area. They include red-eyed vireo, pileated woodpecker, black-throated green warbler, Nashville warbler, downy and hairy woodpeckers, winter wren, white-throated sparrow, red-breasted and white-breasted nut-hatches, chickadee, Eastern wood pewee and blue jay.

Birds that require or utilize shrub swamps and marshes are also common in this area. They include red-winged blackbird, yellowthroat, indigo bunting, cedar waxwing, mallard, wood duck, great blue heron, marsh wren, yellow warbler and song sparrow. There may be a heron rookery in the area. Bald eagles and ospreys are seen often, though not believed to nest in the immediate area.

Common waterfowl that may be found in migration in the flood plain and adjacent larger open waters include mute and tundra swans, American coots, a number of puddle duck and diving duck species, loons, grebes and Canadian geese.

The 100-year flood plain of Pleasant Lake includes approximately 40 acres of National Forest lands on the northwest corner of the lake. National Forest lake frontage is almost all leatherleaf bog with a scattering of tamarack. The tamarack stand becomes more dense farther from the lake and eventually grades into a mixed lowland conifer stand. This flood plain differs from that of Lake Mitchell in that there is less vegetative diversity adjacent to Pleasant Lake.

Important wildlife values of this flood plain are winter deer cover (away from the lake) and snowshoe hare habitat. Small mammal communities (shrews, voles and mice) are probably not as diverse as those found in the Lake Mitchell flood plain.

Bird communities are typical of maturing lowland confiers and include black-throated green warblers, winter wren, chickadee, red-breasted nuthatch, small woodpeckers, blue jay and white-throated sparrow. It is possible that there may be a colony of great blue herons in this flood plain or in adjacent low-land hardwoods.

There appears to be no specific data available regarding stream chemistry, however, from visual observations, the water quality of the Clam River appears to be good. The average river width is 20 feet and the fluctuating depth of flow provides aquatic habitat for several fishes and other aquatic and semi-aquatic species. The Michigan Department of Natural Resources classify the Clam River as a cool water fishery stream with species composition that includes bass, pike, sunfish, bullhead and minnows.

According to the U.S. Forest Service, there are many archaeological features in the flood plain areas. There are several prehistoric burial sites on the Lake Cadillac shoreline. Existing mounds have been identified on both north and south shores. A total of approximately 17 mounds have so far been discovered along the shore of Lake Cadillac and Lake Mitchell. Near the dam on the Clam River is the site of a prehistoric village, and evidence such as subsurface remains, pilings and other items indicate old lumber mills along both lakeshores. In addition, old campsites are present around both lakes.

FLOOD PROBLEMS

Annual flooding occurs in the early spring due to a combination of snowmelt and rainfall, and occasionally in the fall due to heavy rains.

Lake Mitchell and Lake Cadillac:

Frequent flooding occurs in areas northwest of Lake Mitchell. These areas, which are shown as flood prone areas, are located outside of and above Lake Mitchell's flood plain. Flooding occurring in flood prone areas is due to either inadequate or no road crossings or high water table soils. Drainage plans need to be developed and implemented in these flood prone areas. Although this is beyond the scope of this study, a number of recommendations are listed on page 16. The 500-year flood inundates approximately 590 acres around Lake Cadillac and Lake Mitchell. About 20 residences would experience first floor damage. In addition, approximately 1,150 acres of flood prone areas are shown within the study limits. Forty-five residences are located in these areas.

Clam River:

Flood damages are usually confined to homes and businesses along the river, particularly in the northern areas of the city of Cadillac. Some basement flooding is occurring in areas outside of the flood plain. The 100-year flood inundates approximately 220 acres. Forty-nine residences and six businesses would experience flooding during a 100-year flood.

Pleasant Lake:

Considerable flooding regularly occurs around Pleasant Lake. This is due to an inadequate outlet. The Wexford County Drain Commissioner has retained the services of an engineering firm to address this problem. The 100-year event floods approximately 120 acres. Twelve houses are flooded.

This study reports high water profiles and areas subject to flooding based on analyses of existing stream hydraulics and current watershed and flood plain land use and cover. Water surface profiles along the Clam River are plotted for the 10-, 50-, 100- and 500-year flood events. The expected extent of inundation from two floods, the 100-year and 500-year, is shown on the aerial photomaps. The photomaps indicate the approximate areas subject to flooding by the two floods, under present conditions.

To determine expected flood levels at a specific location use Sheet Index, Figure 2 (Appendix A), and refer to the appropriate Flood Hazard Photomaps to determine the location of the nearest surveyed section and the general area affected. Then, refer to the adjacent plotted high water profiles to determine the mean sea level flood elevations for that location. Profile elevations may also be used to determine the extent or depth of flooding in any given area by use of detailed field surveys.

Typical valley sections shown in Appendix B indicate the effects of the four floods. Flood discharges used for computing high water profiles in the study area are shown in Table 1 in Appendix C. Table 2 in Appendix C shows flood elevations at each of the surveyed valley sections for present conditions.

While no computations were made to reflect the problems of ice and debris blockage at bridges, because of the wide possible variations in conditions, a few generalized comments can be made. Ice and debris can often totally block an opening. To determine possible effects, look at the high water profile sheets. At each bridge or culvert, a "low point or road overflow" symbol is shown. Based on field surveys, this is the elevation at which the road would flood. If there is no culvert capacity available, all flows would need to go over the road through this low section. The depth of flow and flooding would depend on the quantity of flow, as well as cross-sectional area available for flow.

EXISTING FLOOD PLAIN MANAGEMENT

Currently, Cherry Grove, Clam Lake and Haring Townships have no existing flood plain ordinances or flood insurance. Selma Township residents became eligible for flood insurance in 1986. Flood insurance is available for residents of the city of Cadillac. An ordinance passed in 1984 sets the 100-year flood elevation of Lake Cadillac and Lake Mitchell at elevation 1291.6 feet.

ALTERNATIVES FOR FLOOD PLAIN MANAGEMENT

The objective of flood plain management is to encourage land use and development in such a manner as to minimize potential flood damage. Basic goals are to guide flood plain development consistent with the requirements of nature and the needs of the local area. Flood plain management can:

1. Prohibit uses which are dangerous to public health or safety in times of flood.
2. Restrict building or other development which may cause increased flood heights or velocities.
3. Require that public or private facilities that are vulnerable to floods be protected against flood damage at the time of construction.
4. Protect individuals from investments in flood hazard areas which are unsuited for their intended purposes.

There are numerous flood plain management alternative categories and tools that can be employed to accomplish the above objectives and goals. The ones that apply to this area are suggested below. Other flood plain management techniques should be considered and may well prove to be effective in reducing or preventing flood damages. Many of the road crossings should be resized when replacement is necessary.

Present Condition

This is the "no change" alternative which reflects ongoing flood plain development pressures and management trends. Local governmental units can continue to plan, zone and accept or reject requests for alternative flood plain and adjacent land uses. Flood problems may continue to increase if development continues.

Land Treatment

This alternative discusses opportunities to minimize or decrease changes in upland runoff and erosion because of land use changes. The traditional approach of accelerating conservation land treatment, by working with landowners to install conservation practices, will minimize soil erosion and reduce runoff. Installation of such measures as tree planting, windbreaks, forest management, permanent vegetative cover and on-site water storage will all reduce runoff, erosion and sedimentation.

As rural areas urbanize, the increase in peak discharges due to more efficient conveyance paths and increased impervious areas can have a significant adverse impact on downstream areas. There is a growing interest on the part of planners, developers and the public in protecting downstream areas from induced flood damages that may accompany increased peaks and stages. Planning authorities are proposing local ordinances that restrict the type of development permitted and the impact development can have on the watershed. One of the primary controls that could be imposed is that future-condition discharges cannot exceed present-condition discharges at some predetermined frequency of occurrence at specified points on the channel.

Methods to control runoff in urbanizing areas reduce either the volume or the rate of runoff. The effectiveness of any control method depends on the available storage, the outflow rate and the inflow rate. Because a great variety of methods can be used to control peak flows, each method proposed should be evaluated for its effectiveness in the given area.

MEASURES FOR REDUCING AND DELAYING URBAN STORM RUNOFF

Area	Reducing Runoff	Delaying Runoff
Parking Lots	<ol style="list-style-type: none">1. Porous pavement<ol style="list-style-type: none">a. Gravel parking lotsb. Porous or punctured asphalt2. Concrete vaults and cisterns beneath parking lots in high value areas3. Vegetated ponding areas around parking lots4. Gravel trenches	<ol style="list-style-type: none">1. Grassy strips on parking lots2. Grassed waterways draining parking lot3. Ponding and detention measure for impervious areas<ol style="list-style-type: none">a. Rippled pavementb. Depressionsc. Basins
Residential	<ol style="list-style-type: none">1. Cisterns for individual homes or groups of homes2. Gravel driveways (porous)3. Contoured landscape4. Groundwater recharge<ol style="list-style-type: none">a. Perforated pipeb. Gravel (sand)c. Trenchd. Porous pipee. Dry wells5. Vegetated depressions	<ol style="list-style-type: none">1. Reservoir or detention basin2. Planting a high delaying grass (high roughness)3. Gravel driveways4. Grassy gutters or channels5. Increased length of travel of runoff by means of gutters or diversions.

Preservation and Restoration of Natural Values

Flood plains, in their natural or relatively undisturbed state, provide three broad sets of natural and beneficial resources and resource values.

Water resource values include natural moderation of floods, water quality maintenance and groundwater recharge. The physical characteristics of the flood plain shape flood flows. Flood plains generally provide a broad area to spread out and temporarily store flood waters. This reduces flood peaks and velocities and the potential for erosion.

Flood plains serve important functions in protecting the physical, biological and chemical integrity of water. A vegetated flood plain slows the surface runoff, causing it to drop most of its sediment load on the flood plain. Pathogens and toxic substances entering the main water body through surface runoff and accompanying sediments are decreased.

The natural flood plain has surface conditions favoring local ponding and flood detention, plus subsurface conditions favoring infiltration and storage. The slowing of runoff provides additional time for it to infiltrate and recharge available ground water aquifers, and also provides for natural purification of the waters.

Flood plains support large and diverse populations of plants and animals. In addition, they provide habitat and critical sources of energy and nutrients for organisms in adjacent and downstream terrestrial and aquatic ecosystems. The wide variety of plants and animals supported directly and indirectly by flood plains constitutes an extremely valuable, renewable resource important to economic welfare, enjoyment and physical well-being.

The flood plain is biologically important because it is the place where land and water meet and the elements of both terrestrial and aquatic ecosystems mix. Shading of the stream by flood plain vegetation moderates water temperatures; roots and fallen trees provide instream habitat; and near stream vegetation filters runoff, removing harmful sediments and buffering pollutants, to further enhance instream environments.

Flood plains contain cultural resources important to the nation and to individual localities. Native American settlements and early cities were located along the coasts and rivers in order to have access to water supply, waste disposal and water transportation. Consequently, flood plains include most of the nation's earliest archeological and historical sites. In addition to their historical richness, flood plains may contain invaluable resources for scientific research. For example, where flood plains contain unique ecological habitats, they make excellent areas for scientific study. Flood plains may provide open space community resources. In urban communities, they may provide green belt areas to break urban development monotony, absorb noise, clean the air and lower temperatures. Flood plain parks can also serve as nature study centers and laboratories for outdoor learning experiences.

It is recommended that several selected open space areas be preserved, especially in the undeveloped areas. Their preservation, in accordance with soil limitations and good land use management, will reduce development hazards, prevent additional future flood damages and enhance the urban environment.

1. Soils with high water tables should be retained in natural vegetation. No commercial or residential construction should take place on these soils since the limitations are very severe. The Soil Conservation Service has completed a detailed soil survey of Wexford County. Copies of the material, including maps and interpretations, are available for reference in the Wexford County Soil Conservation District Office located at 3060 West 13th Street, Cadillac, Michigan 49601-9658. This information can be used to determine the kinds of soils in a given area and their limitations for various uses.
2. Upland open space should be retained in the natural state as much as possible.
3. Private wooded areas on steep slopes should be preserved from all development. Destruction of natural cover on these steep slopes usually causes excessive erosion during construction. Preservation of these wooded sites would also enhance housing developments in the area.

4. Developing areas should provide on-site flood water storage to temporarily store additional runoff volumes and peaks created by their urbanization.
5. Undeveloped flood plain areas should be managed for wildlife and recreation. These areas have potential for an excellent outdoor classroom. The Clam River is easily accessible to many school and college students.

Non-Structural Measures

1. Develop and implement, or update, a flood plain protection and zoning ordinance based on the 100-year frequency high water profile and the flood plain delineations (Appendix A). Retaining the storage in the existing flood plain area will be necessary if this flood profile is to remain valid. Reducing the storage capacity in the system will tend to increase elevations and discharges above that indicated in this report.
2. Floodproof buildings and residences already in the flood plain to reduce flood damages. Some basement windows and doors, floor drains and foundations can be modified to reduce effects of flood waters. Materials and supplies stored in vulnerable positions can be relocated and protected. These modifications can be planned and installed where it is desirable and/or feasible to continue using facilities currently in the flood plain.
3. Plans should be developed for alternate routes for auto, truck and emergency vehicle traffic around those roads that will be inundated during the flood. This will require cooperation between city, township, county and state officials.
4. Maintenance of the Clam River from the outlet at Lake Cadillac through the city of Cadillac appears to be excellent. Debris, fallen trees and brush should be removed at least yearly. Special attention should be given to the Giantway Tubes. The trash racks at the inlet should be kept free of debris at all times. Monthly cleaning is recommended. Snow and ice from road clearing operations should not be piled in the flood plain. The dam should be opened as early in the fall as possible to accommodate spring runoff.
5. Owners and occupiers of all types of buildings and mobile homes should obtain flood insurance coverage for the structure and contents, especially if located within or adjacent to the delineated flood hazard areas. The Sponsors should make necessary applications and pass needed resolutions and zoning ordinances to qualify for subsidized federal flood insurance. Contact the Land and Water Management Division, Michigan Department of Natural Resources, Mason Building, P.O. Box 30028, Lansing, Michigan 48909 for additional information.

Structural Measures

Flood stages in Lake Cadillac and Lake Mitchell could be reduced by improving flow conditions with the Clam River by increasing the channel's carrying capacity. This would require a considerable amount of channel excavation with improved bridge openings. Any attempt to reduce flood elevations around Pleasant Lake will require the construction of an outlet channel. This channel could be outletted either into the Ball Drain or rerouted to Lake Cadillac and Lake Mitchell. In any event, downstream flooding would need to be evaluated.

ALTERNATIVES FOR FLOOD PRONE AREAS

Flood prone areas northwest of Lake Mitchell, although well above the 100- and 500-year flood elevation, experience periodic flooding.

Many of the flood plain management tools discussed earlier also apply for this area. The ones that apply are mentioned below.

Present Condition

This is the "no change" alternative which reflects ongoing development pressures and management trends. Local governmental units can continue to plan, zone and accept or reject requests for adjacent land use changes. Flooding problems may continue to increase if development continues.

Preservation of Natural Areas

It is recommended that several selected open space areas be preserved, especially in the undeveloped areas. Their preservation, in accordance with soil limitations and good land use management, will reduce development hazards, prevent additional future flood damages and enhance the urban environment.

1. Soil with high water tables should be retained in natural vegetation. No commercial or residential construction should take place on these soils since the limitations are very severe.
2. Upland open space should be retained in the natural state as much as possible.
3. Developing areas should provide on-site water storage to temporarily store additional runoff volumes and peaks created by their urbanization.
4. Undeveloped flood prone areas should be managed for wildlife and recreation.

Non-Structural Measures

1. Floodproof buildings and residences already in these flood prone areas to reduce flood damages. Some basement windows and doors, floor drains and foundations can be modified to reduce effects of flood waters. Materials and supplies stored in vulnerable positions can be relocated and protected. These modifications can be planned and installed where feasible to continue using facilities currently in the flood prone area.
2. Maintenance of the Clam River from the outlet at Lake Cadillac through the city of Cadillac appears to be excellent. The maintenance should continue. In addition, the dam should be opened as early in the fall as possible. This will reduce the fluctuation of Lake Mitchell's level during spring runoff.

Structural Measures

Detailed drainage plans need to be developed for this area. Options include: a diversion around the north end of this developed area, a pump tile drainage system or a combination of the two. The services of an engineering firm will need to be retained to further investigate this potential solution.

APPENDIX A



LEGEND

- WATERSHED BOUNDARY
- 27 SHEET COVERAGE



VICINITY MAP

Figure No. 2

PHOTO SHEET INDEX CLAM RIVER FLOOD PLAIN MANAGEMENT STUDY WEXFORD COUNTY, MICHIGAN

0 1 2
MILES
0 1 2
KILOMETERS

SOURCE:
1983 GENERAL HIGHWAY MAP AND
INFORMATION FROM SCS FIELD PERSONNEL.
POLYCONIC PROJECTION

VALLEY
SECTIONS

ELEVATION ABOVE MEAN SEA LEVEL
IN FEET
(NATIONAL GEODETIC VERTICAL DATUM of 1929)

STUDY LIMIT 49 ROAD 10.0

0+00

5+00

10+00

15+00

20+00

25+00

30+00

35+00

40+00

45+00

NOTE:
Additional field measured cross-sections may be needed
to verify the water surface profile between the cross-
sections used in this report. When the difference in
the elevation of the channel bottom between cross-
sections exceeds 2/3 the depth of flood flows,
variations in the channel bottom can cause
significant changes in the flood profiles.

STATIONS ALONG CENTERLINE
IN FEET

LOW BANK ELEVATION

EXISTING CHANNEL BOTTOM

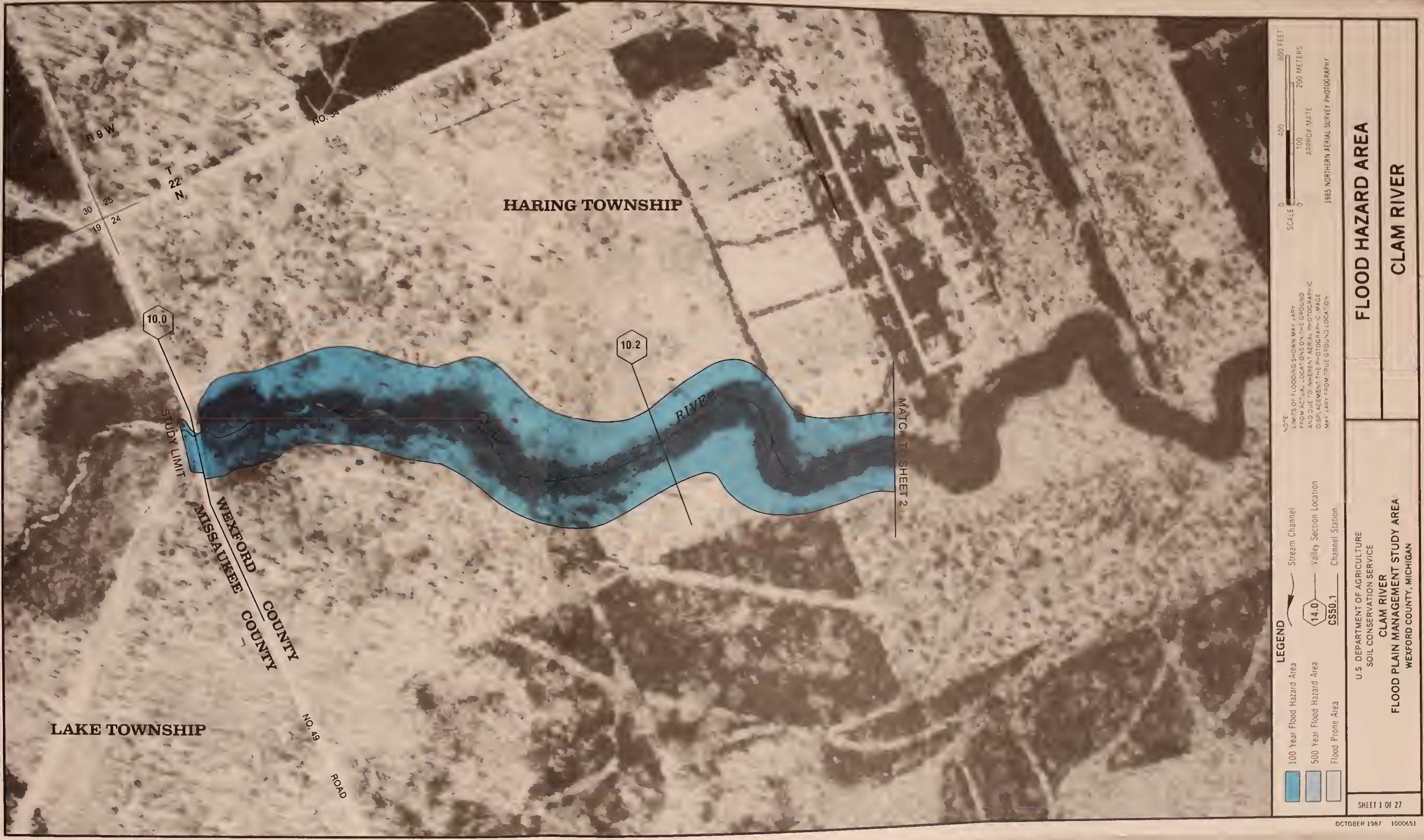
Bridge Deck
Road Flow
Top of C.M.P.
Invert of C.M.P.

50-YR
100-YR
50-YR
10-YR

HIGH WATER PROFILES

CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE	
Designed T. D. BOURDON	Approved by _____ Title _____
Drawn C. N. WADE	10-86
Traced _____	Title _____
Checked R. H. BAUERLE	Sheet No. 1 Drawing No. _____ of 8



VALLEY SECTIONS

1280

1270

1260

1250

ELEVATION ABOVE MEAN SEA LEVEL
(NATIONAL GEOGRAPHIC VERTICAL DATUM of 1929)

45+00

50+00

55+00

60+00

65+00

70+00

75+00

80+00

85+00

1280

1280

1270

1260

1250

10-3

10-5

LOW BANK ELEVATION

EXISTING CHANNEL BOTTOM

STATIONS ALONG CENTERLINE
IN FEET

HIGH WATER PROFILES

NOTE:
Additional field measured cross-sections may be needed
to verify the water surface profile between the cross-
sections used in this report. When the difference in
the elevation of the channel bottom between cross-
sections exceeds 2/3 the depth of flood flows,
variations in the channel bottom can cause
significant changes in the flood profiles.

CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN

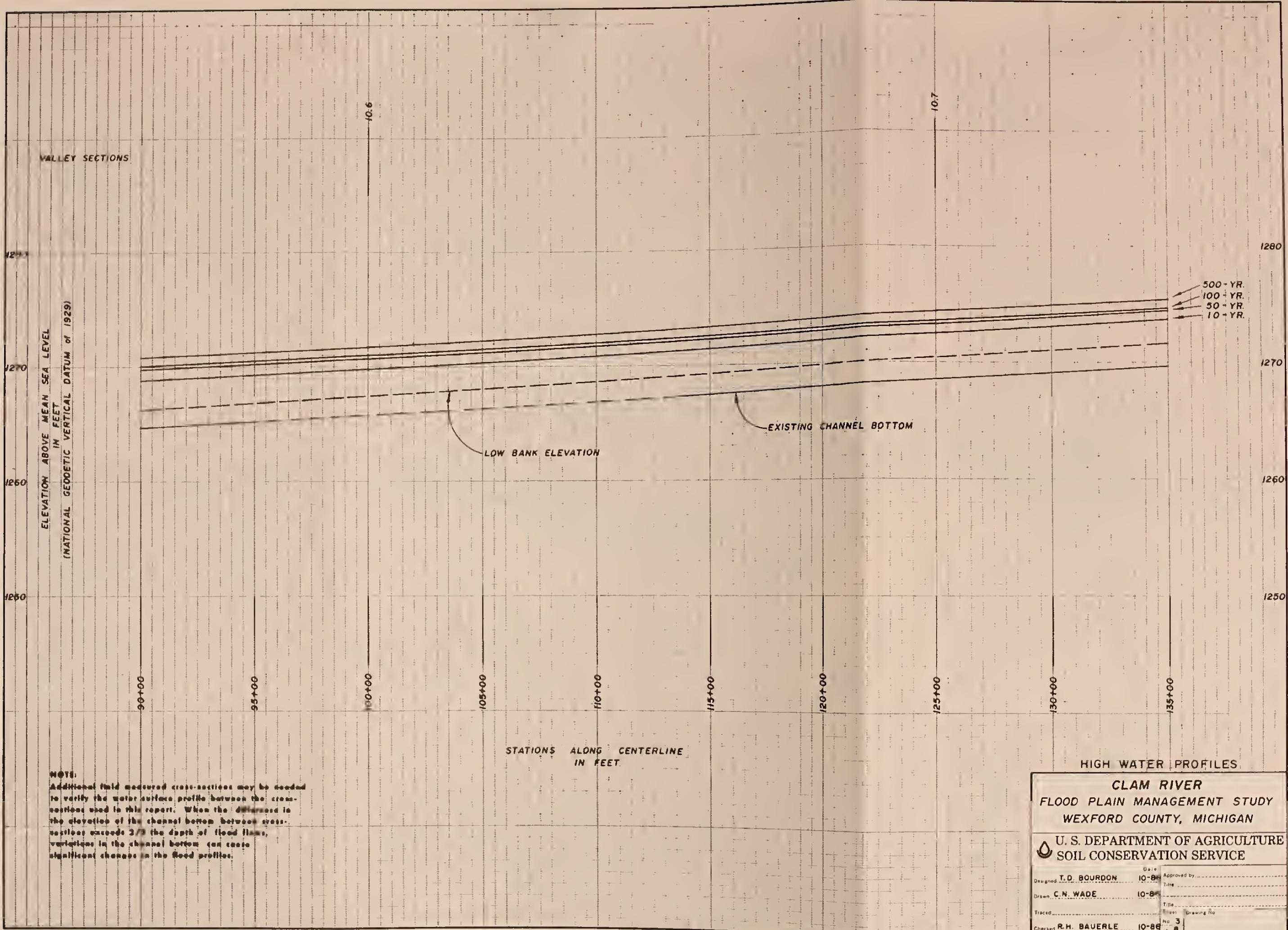
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	T. O. BOUROON	Date	Approved by
Drawn	C. N. WADE	Date	
Checked	R. H. BAUERLE	Date	
No. 2	Drawing No		
of 8			



VALLEY SECTIONS

ELEVATION ABOVE MEAN SEA LEVEL
IN FEET
(NATIONAL GEODETIC VERTICAL DATUM as 1929)



NOTE:
Additional field measured cross-sections may be needed
to verify the water surface profile between the cross-
sections used in this report. When the difference in
the elevation of the channel bottom between sections
exceeds 2/3 the depth of flood flows,
variations in the channel bottom can cause
significant changes in the flood profiles.

HIGH WATER PROFILES

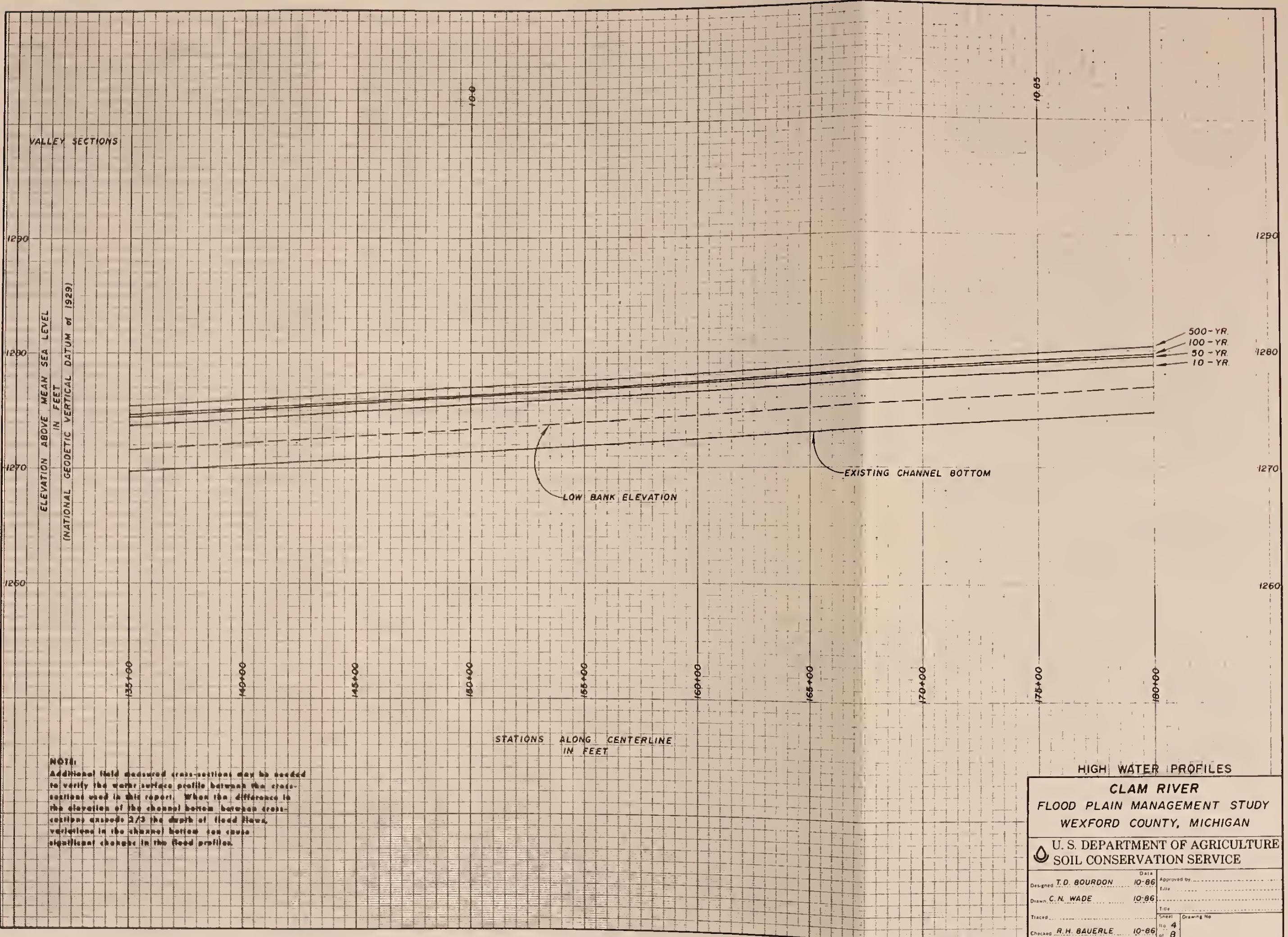
CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed.....	T. D. BOURDON	Date.....	10-89	Approved by.....
Drawn.....	C. N. WADE	Title.....		Title.....
Traced.....				
Checked.....	R. H. BAUERLE	Date.....	10-89	Drawing No. 3 of 8



USDA SCS NATIONAL CARTOGRAPHIC CENTER FT WORTH TX 1987



NOTE:
Additional field measured cross-sections may be needed
to verify the water surface profile between the cross-
sections used in this report. When the difference in
the elevation of the channel bottom between cross-
sections exceeds 2/3 the depth of flood flows,
variations in the channel bottom can cause
significant changes in the flood profiles.

HIGH WATER PROFILES

CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE		Data
Designed	T. D. BOURDON	10-86
Drawn	C. N. WADE	10-86
Traced		
Checked	R. H. BAUERLE	10-86
	No. 4	Drawing No.
	or 8	

HARING TOWNSHIP

NO. 34

ROAD

MATCH

FEET 3

10.8

T 22 N

R 9 W

26

23

22

0.85

MATCH

- LEGEND
- 100 Year Flood Hazard Area
 - Stream Channel
 - 14.0 1a & Section Location
 - 500 Year Flood Hazard Area
 - CS50.1 Channel Section
 - Flood Plain Area

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY AREA
WEXFORD COUNTY, MICHIGAN

NOTE: LINES OF FLOODING SHOWN MAY NOT PROACTUAL LOCATIONS ON THE GROUND.
PROJECT NUMBER: AERIAL PHOTOGRAPHIC
DISPLACEMENT: 100 FEET
VALLEY FLOOR TRUE SPOT NO. LOCATION:

SCALE: 0 400 FEET
0 200 METERS
APPROX. NAD 72
1955 NORTHERN AERIAL SURVEY PHOTOGRAPH

FLOOD HAZARD AREA

CLAM RIVER

SHEET 4 OF 27

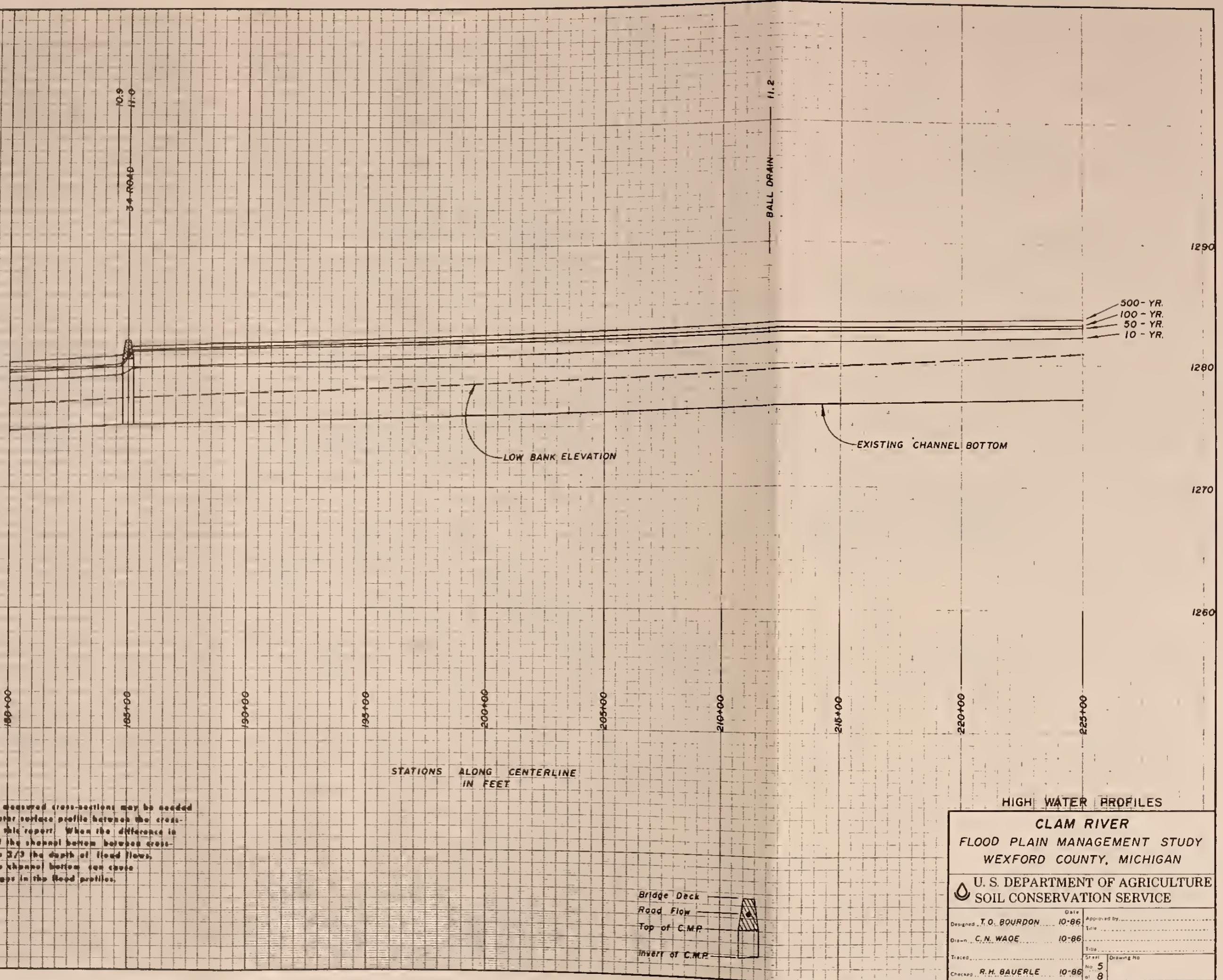
OCTOBER 1987 1000651

VALLEY SECTIONS

1290

ELEVATION ABOVE MEAN SEA LEVEL
IN FEET

(NATIONAL GEODETIC VERTICAL DATUM of 1929)





FLOOD HAZARD AREA

CLAM RIVER

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY AREA
WEXFORD COUNTY, MICHIGAN

SHEET 5 OF 27

VALLEY SECTIONS

1300

1890

四百一

METHO-

ELEVATION ABOVE MEAN SEA LEVEL IN FEET	GEODETIC VERTICAL DATUM OF ONAL
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NATIONAL GEODETIC VERTICAL DATUM of 1929

四

Additional field measured cross-sections may be needed to verify the water surface profile between the cross-sections used in this report. When the difference in the elevation of the channel bottom between cross-sections exceeds 2/3 the depth of flood flows, variations in the channel bottom may cause significant changes in the flood profiles.

四
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LOW BANK ELEVATION

EXISTING CHANNEL BOTTOM

**STATIONS ALONG CENTERLINE
IN FEET**

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- 270 + 80

HIGH WATER PROFILES

CLAM RIVER

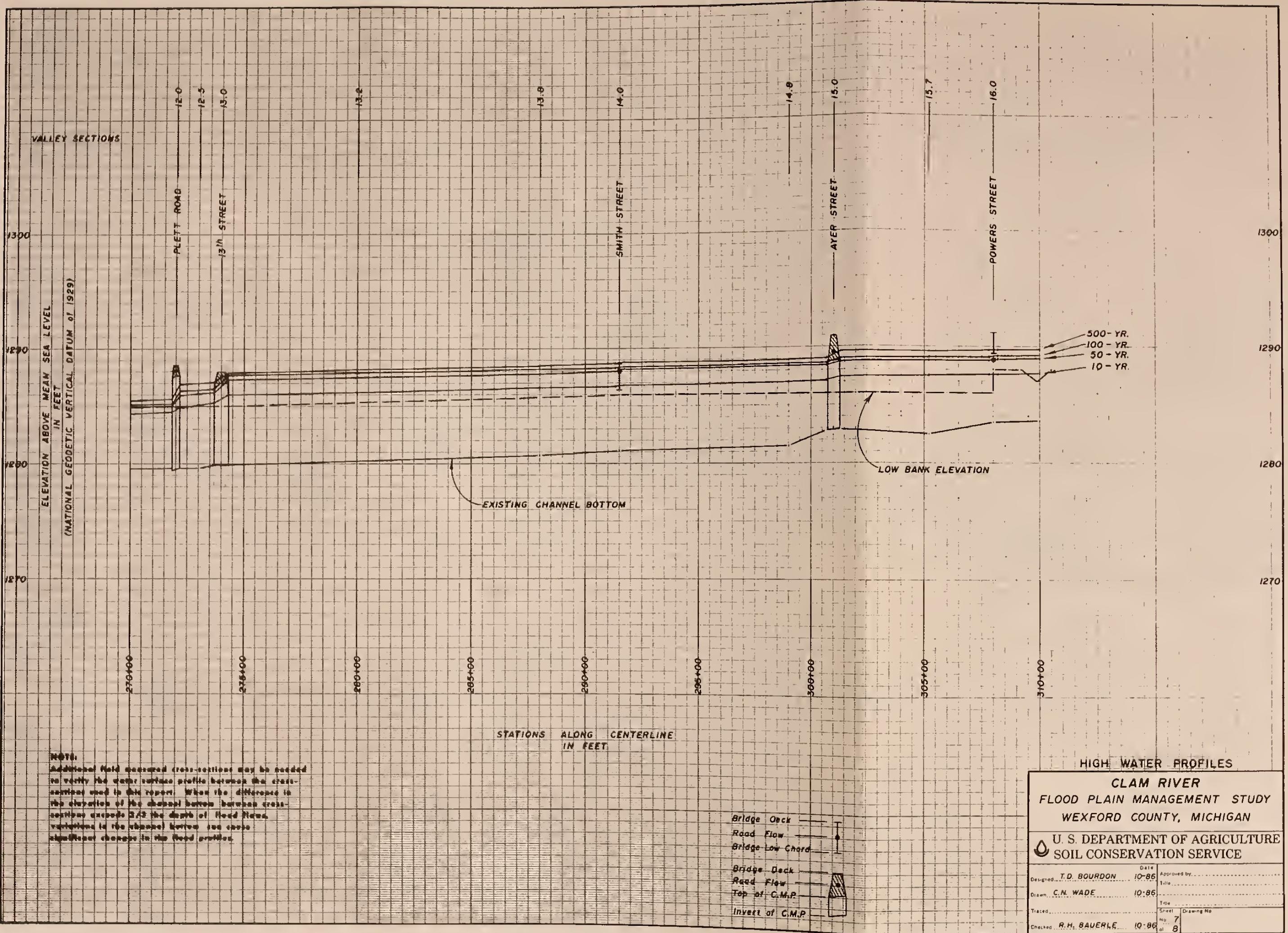
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN



 U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	T.O. BOUROON	Date	Approved by
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Revised		Date	
Checked	R.H. BAUERLE	Sheet	Drawing No.
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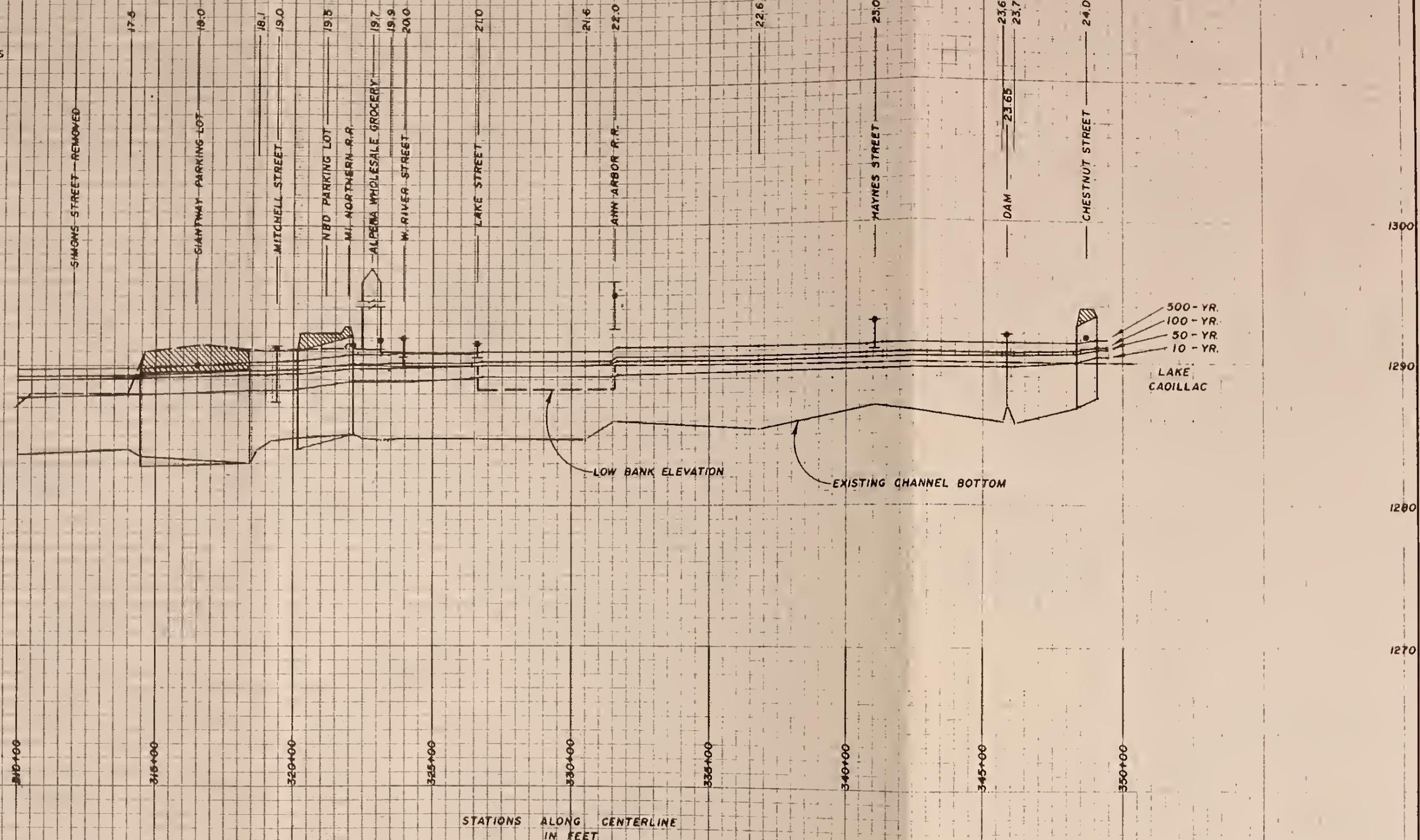




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ELEVATION ABOVE MEAN SEA LEVEL
IN FEET
(NATIONAL GEODETIC VERTICAL DATUM of 1929)

VALLEY SECTIONS



NOTE:
Additional field measured cross-sections may be needed
to verify the water surface profile between the cross-
sections used in this report. When the difference in
top elevation of the channel bottom between cross-
sections exceeds 2/3 the depth of flood flows
corresponding to the channel bottom, see chart
for channel changes in the flood profile.

HIGH WATER PROFILES

CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
WEXFORD COUNTY, MICHIGAN

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	T. D. BOURDON	10-86	Approved by
Drawn	C. N. WADE	10-86	Title
Traced			Date
Checked	R. H. BAUERLE	10-86	No. 8 of 8



FLOOD HAZARD AREA	CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY AREA	
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE CLAM RIVER WEXFORD COUNTY, MICHIGAN	
1955 NORTHERN AERIAL SURVEY PHOTOGRAPHY	













NOTE: LINES OF FLOODING SHOWN MAY NOT BE EXACT LOCATIONS ON THE GROUND AND DUE TO NATURE OF AERIAL PHOTOGRAPHIC IMAGE DISPLACEMENT THE PHOTOGRAPHIC IMAGE MAY vary FROM TRUE SPOT-ON LOCATION.

SCALE: 0 400 FEET
0 200 METERS
APPROX. RATE
1925 NORTHERN AERIAL SURVEY PHOTOGRAPH

FLOOD HAZARD AREA

CLAM RIVER





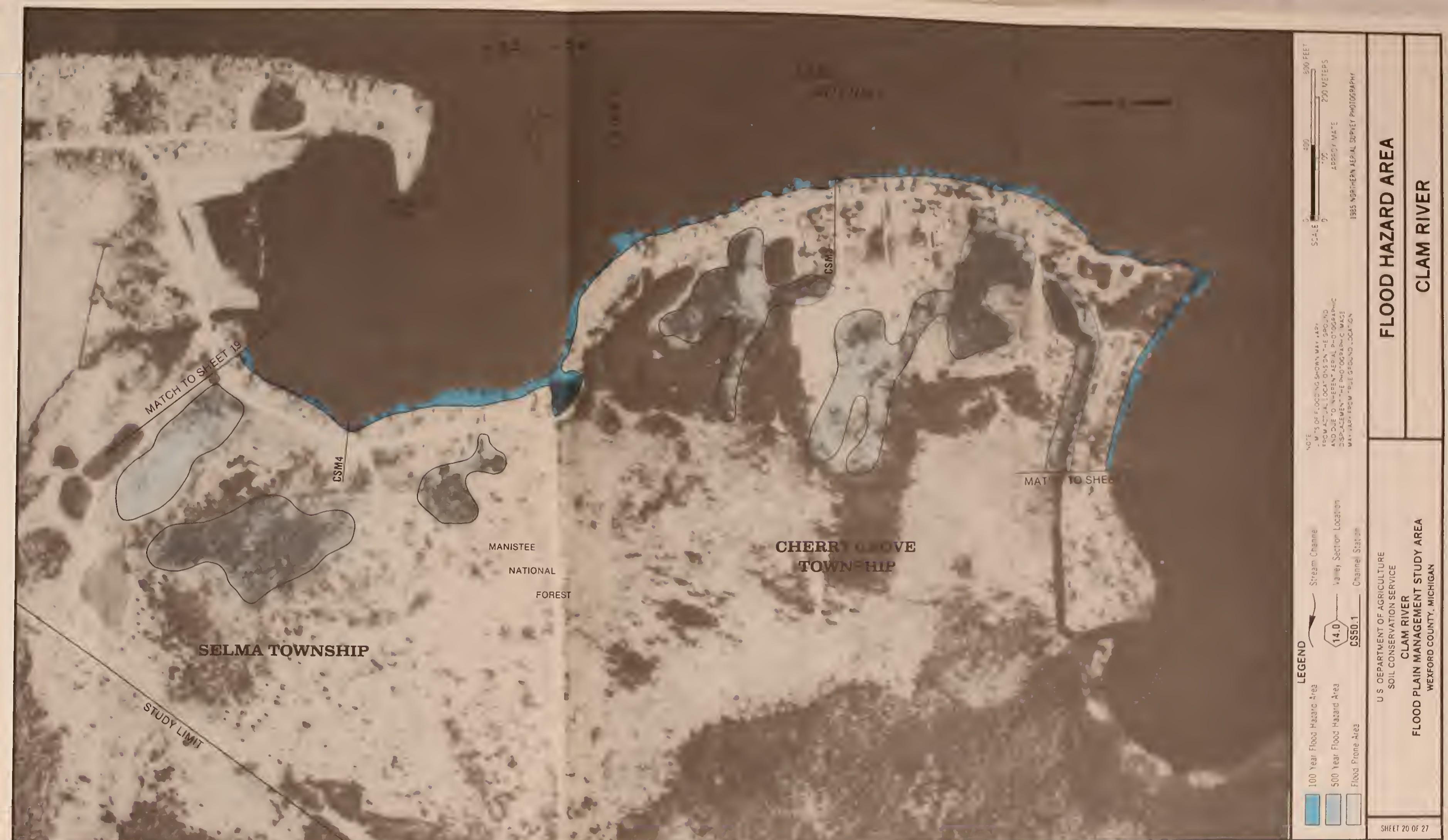
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NOTE: WATER LEVELS SHOWN MAY BE SOONER OR LATER THAN THE SURVEY AND DUE TO DIFFERENT AERIAL PHOTOGRAPHIC DISPLACEMENT THE PHOTOGRAPHIC BASE MAP MAY NOT BE GEODEMICALLY ACCURATE

1935 NORTHERN AERIAL SURVEY PHOTOGRAPH

ADDOCK MAP
250 METERS
200 FEET

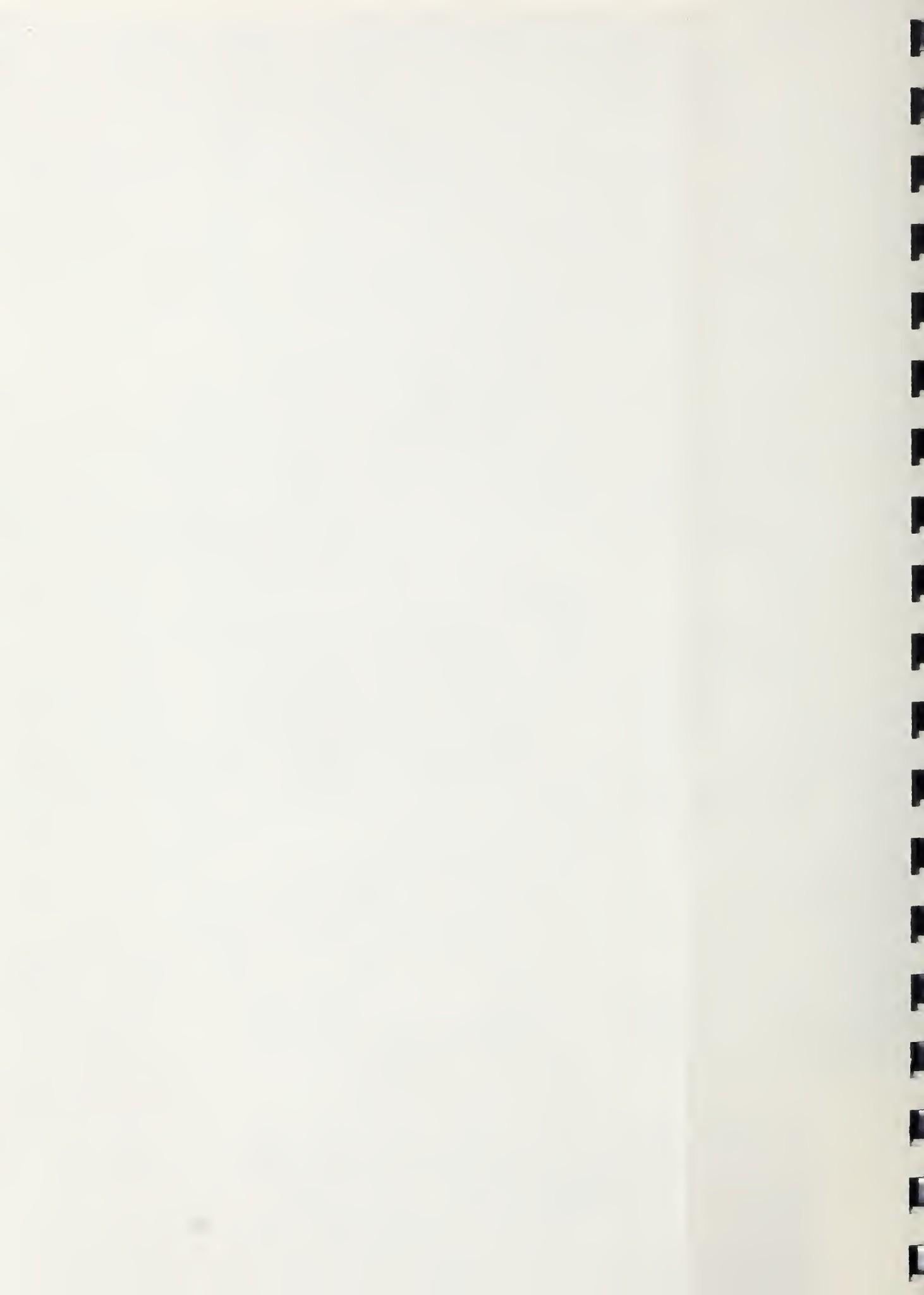
US DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FLOOD PLAIN MANAGEMENT STUDY AREA
CLAM RIVER
WEXFORD COUNTY, MICHIGAN

FLOOD HAZARD AREA

CLAM RIVER



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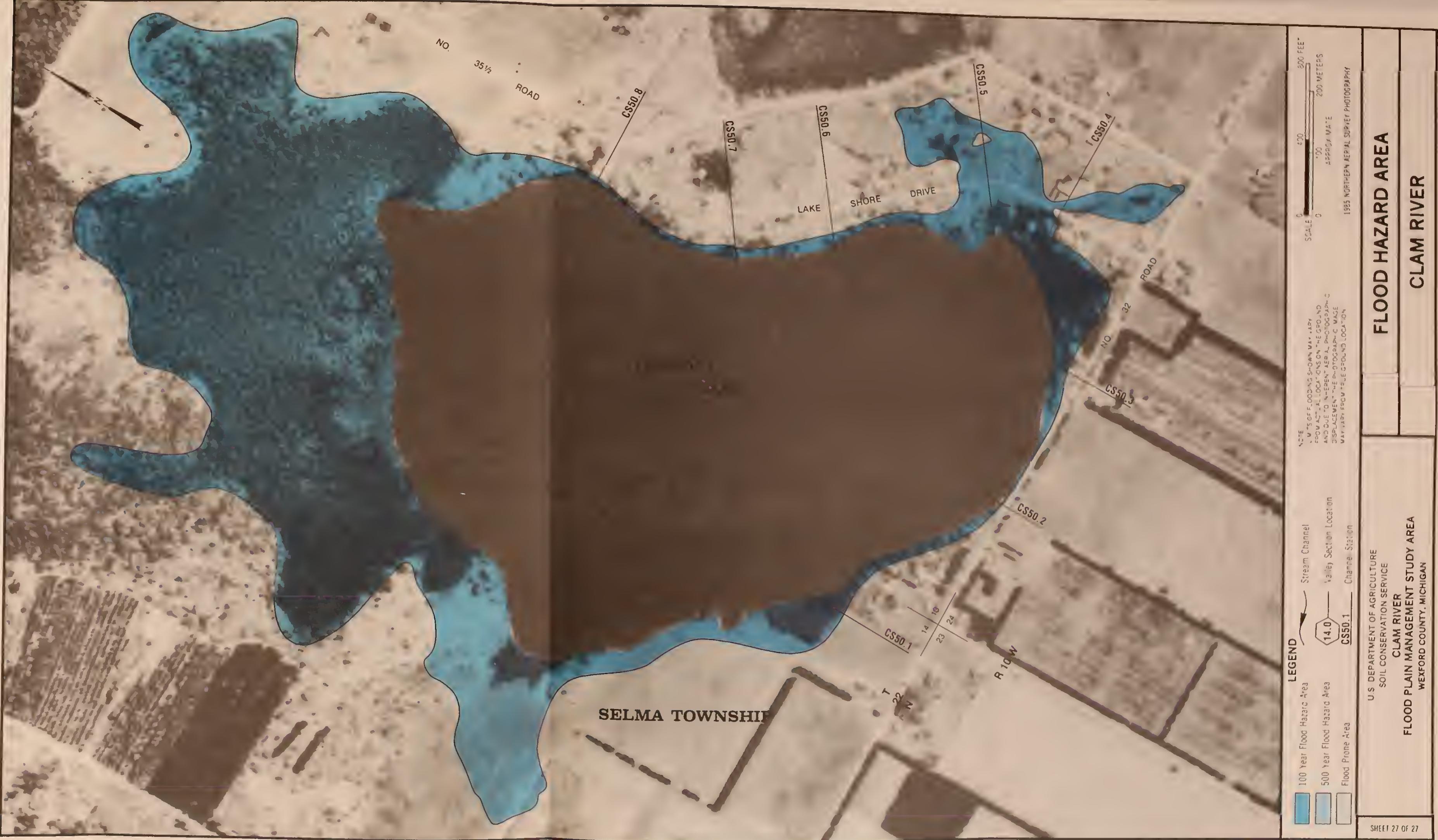




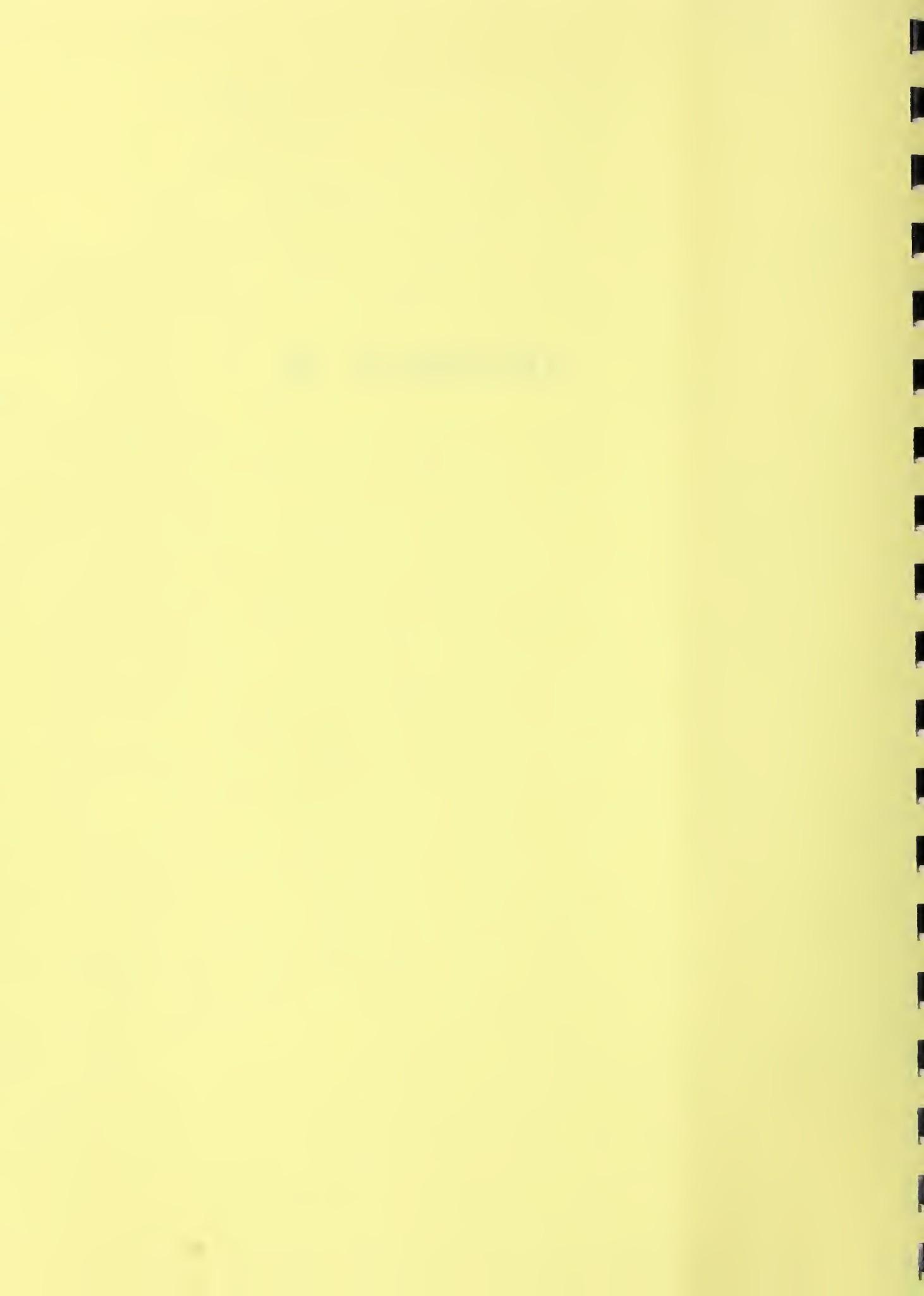


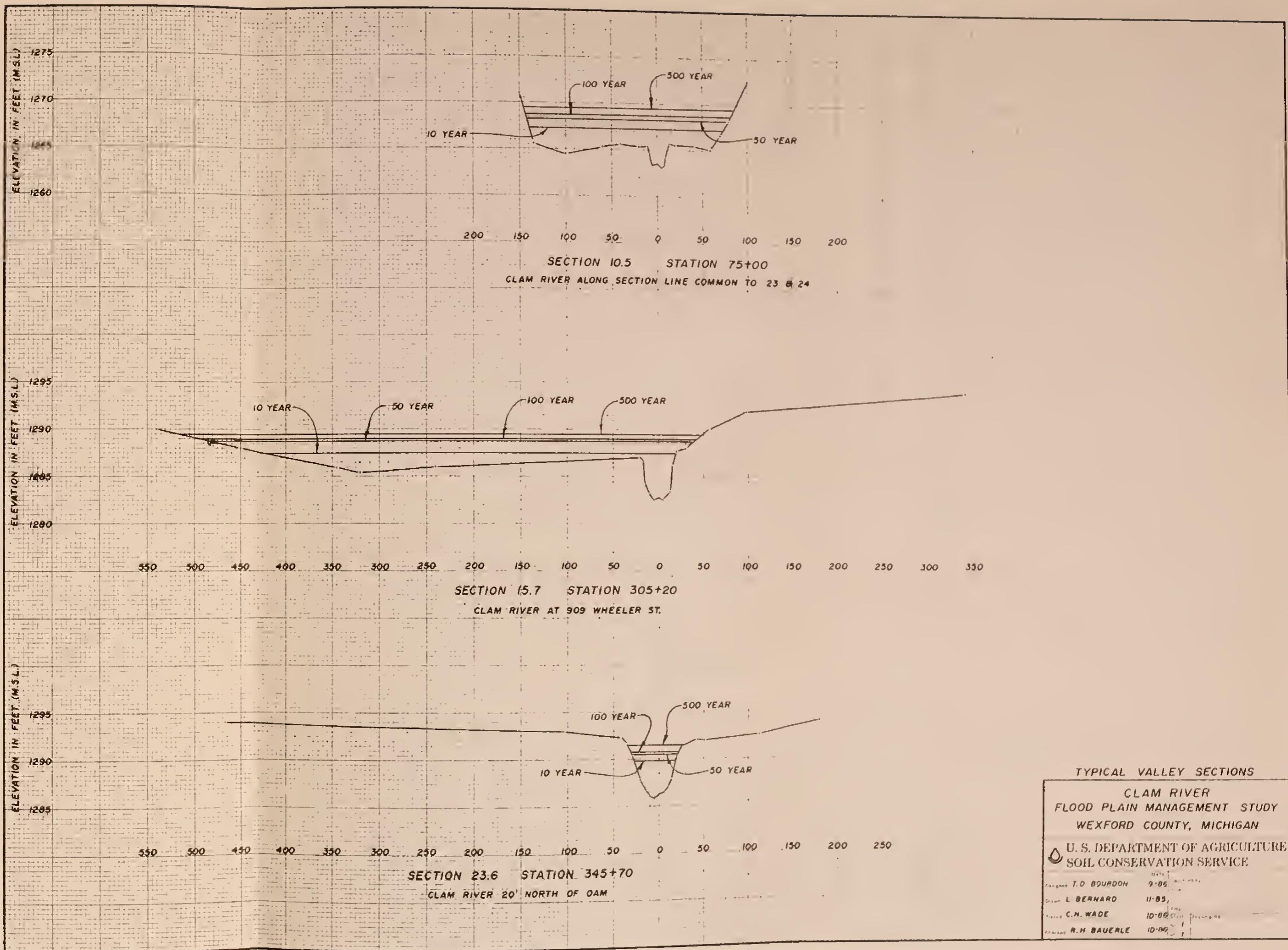






APPENDIX B







APPENDIX C

TABLE 1 - FLOOD DISCHARGES
PRESENT CONDITIONS
Clam River

Location	TR-20 Sec.	From Sec.	To Sec.	Drainage Area Sq. Miles	Estimated Peak Discharges			
					10-Yr. -Cubic Feet	50-Yr. Per Second	100-Yr.	500-Yr.
Lake Cadillac (Base Flow)	01			74.39	105	120	125	135
To Ann Arbor R.R.	004	24.1	22.9	74.43	115	130	140	155
To Mitchell St.	006	22.6	18.9	74.50	130	160	170	200
To Below Giantway Tubes	009	18.1	17.9	74.58	150	190	205	245
To Power St.	012	17.5	17.5	74.66	170	225	245	295
To Smith St.	015	16.1	14.8	74.81	195	275	305	375
To the Ball Drain	022	14.1	11.3	93.97	230	335	360	445
To 49 Rd.	030	11.2	10.0	99.87	230	390	460	655
Pleasant Lake	01			4.25	1	2	4	6

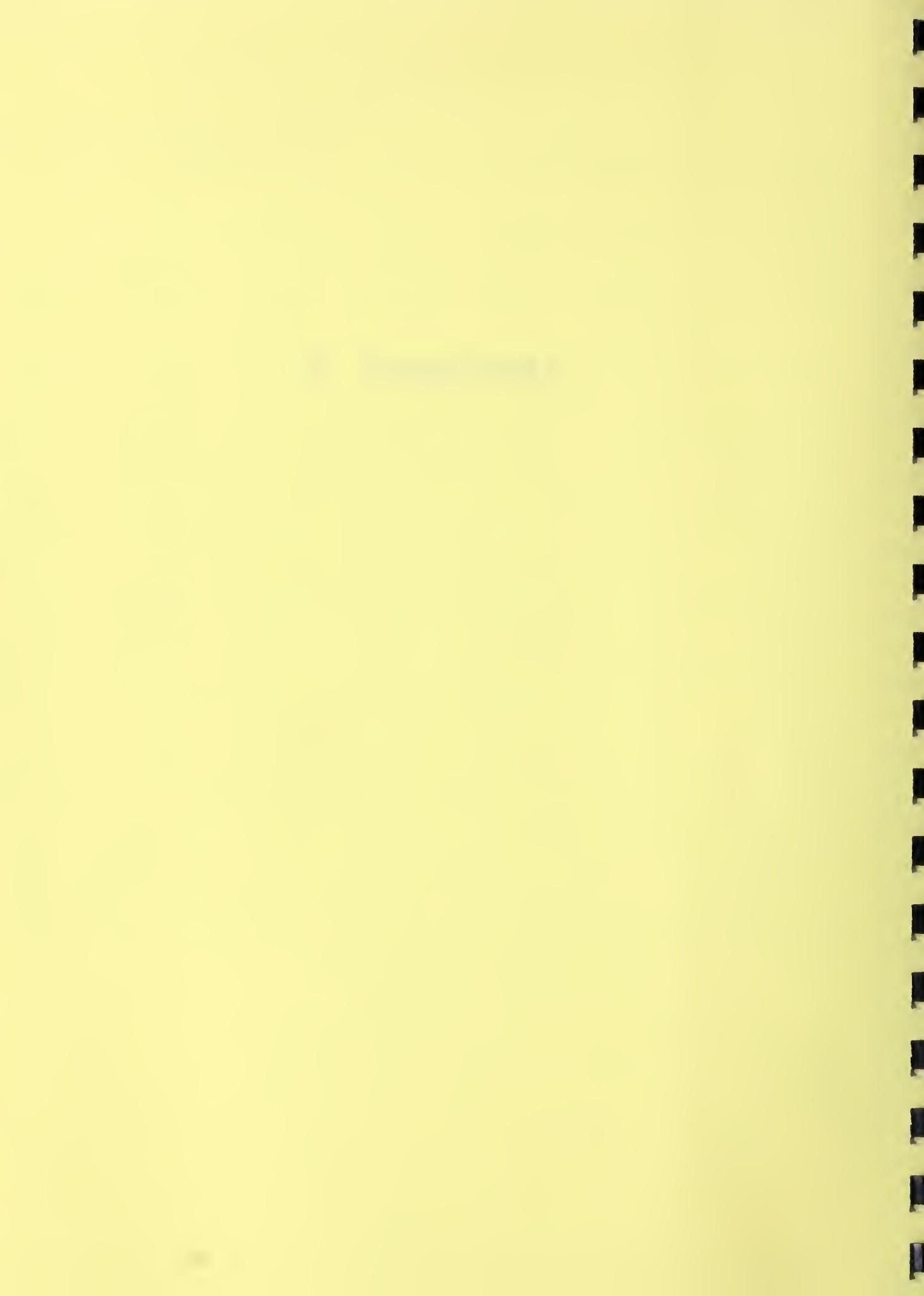
TABLE 2 - FLOOD ELEVATIONS AT SECTIONS
PRESENT CONDITIONS
Clam River

Location	Section	Station	10-Year	50-Year	100-Year	500-Year
Clam River						
49 Road	10.0 D	0+00	1261.3	1261.8	1261.9	1262.4
	10.0 U	0+46	1263.1	1264.4	1264.5	1264.7
	10.2	25+00	1264.2	1265.3	1265.6	1266.2
	10.3	50+00	1265.8	1266.8	1267.0	1267.7
	10.5	75+00	1267.3	1268.3	1268.7	1269.5
	10.6	100+00	1269.8	1270.7	1271.0	1271.7
	10.7	125+00	1272.5	1273.3	1273.6	1274.4
	10.8	150+00	1275.5	1276.2	1276.3	1277.0
	10.85	175+00	1278.2	1279.0	1279.2	1279.8
34 Road	10.9	184+50	1279.3	1280.0	1280.2	1280.9
	11.0 D	184+77	1279.4	1280.1	1280.3	1281.0
	11.0 U	185+23	1279.9	1281.3	1281.4	1281.7
	11.2	212+00	1281.7	1282.6	1282.9	1283.4
	11.3	240+00	1282.9	1283.6	1283.8	1284.2
Plett Road	12.0 D	271+84	1284.5	1285.0	1285.2	1285.6
	12.0 U	272+16	1284.9	1285.9	1286.3	1286.9
	12.5	273+00	1285.1	1286.1	1286.4	1287.0
13th Street	13.0 D	273+69	1285.3	1286.2	1286.5	1287.1
	13.0 U	274+31	1286.0	1287.3	1287.7	1287.9
	13.2	280+00	1286.2	1287.5	1287.9	1288.2
Smith Street	13.8	288+00	1286.6	1287.8	1288.2	1288.5
	14.0 D	291+32	1286.7	1288.0	1288.3	1288.7
	14.0 U	291+68	1286.8	1288.2	1288.4	1288.8
	14.8	299+00	1287.0	1288.4	1288.6	1288.9
Ayer Street	15.0 D	300+73	1287.1	1288.4	1288.6	1289.0
	15.0 U	301+27	1287.4	1288.7	1289.0	1289.6
	15.7	305+20	1287.5	1288.8	1289.1	1289.6
Power Street	16.0 D	307+82	1287.6	1288.8	1289.1	1289.7
	16.0 U	308+18	1287.6	1288.9	1289.2	1289.7
	17.5	314+00	1287.9	1289.1	1289.3	1289.8
Giantway Tubes	18.0 D	314+45	1287.9	1289.1	1289.3	1289.8
	18.0 U	318+45	1288.2	1289.3	1289.6	1290.2
	18.1	318+70	1288.2	1289.3	1289.6	1290.2
Mitchell St.	19.0 D	319+00	1288.2	1289.3	1289.6	1290.2
	19.0 U	319+80	1288.2	1289.4	1289.7	1290.3

TABLE 2 - FLOOD ELEVATIONS AT SECTIONS - CONTINUED
PRESENT CONDITIONS
Clam River

Location	Section	Station	10-Year	50-Year	100-Year	500-Year
NBD Parking Lot & R.R.	19.5 D 19.5 U	320+15 322+15	1288.3 1288.9	1289.4 1289.8	1289.7 1290.1	1290.3 1290.8
Alpena Store	19.7 D 19.7 U 19.9	322+45 323+15 323+45	1288.9 1288.9 1288.9	1289.8 1289.8 1289.8	1290.1 1290.1 1290.2	1290.8 1290.8 1290.8
W. River St.	20.0 D 20.0 U	323+65. 324+25	1288.9 1288.9	1289.9 1289.9	1290.2 1290.2	1290.9 1290.9
Lake Street	21.0 D 21.0 U 21.6	326+41 326+79 330+50	1289.1 1289.2 1289.2	1290.0 1290.0 1290.0	1290.2 1290.3 1290.3	1290.9 1291.0 1291.0
Ann Arbor R.R.	22.0 D 22.0 U 22.6	331+46 331+64 336+80	1289.2 1289.3 1289.5	1290.1 1290.3 1290.3	1290.3 1290.6 1290.6	1291.0 1291.3 1291.3
Haynes Street	23.0 D 23.0 U 23.6	340+73 341+37 345+70	1289.6 1289.6 1289.8	1290.4 1290.4 1290.5	1290.7 1290.7 1290.7	1291.3 1291.3 1291.4
Dam	23.65 23.7	345+85 346+10	1289.8 1289.8	1290.5 1290.5	1290.7 1290.7	1291.4 1291.4
Chestnut St.	24.0 D 24.0 U	348+33 349+07	1290.1 1290.4	1290.7 1290.9	1290.9 1291.1	1291.5 1291.7
Lake Cadillac and Lake Mitchell			1290.8	1291.2	1291.4	1291.7
Pleasant Lake			1329.0	1329.4	1329.5	1329.6

APPENDIX D



INVESTIGATIONS AND ANALYSES

Survey Procedures

Field surveys were made of bridges, roads, structures, channels and flood plains around Lake Cadillac and Lake Mitchell by the Soil Conservation Service in 1985 and around Pleasant Lake in 1986. Temporary bench marks based on USC & GS mean sea level elevations data of 1929 were also set at this time and used for this study. In addition, several temporary bench marks, previously set by the city of Cadillac were used. Surveys were made using second order accuracy. Temporary bench marks are described in Appendix E.

For the Clam River, 18 valley and channel cross-sections plus 22 roads, bridges and structures were surveyed. Eight shoreline cross-sections were surveyed around Lake Cadillac and Lake Mitchell. Eight shoreline cross-sections were surveyed around Pleasant Lake. Six valley and channel cross-sections plus two roads and bridges were surveyed for Pleasant Lake. Aerial photography flown on April 28, 1985 was used as a base for the photo mosaic sheets used to delineate the flood plains. U.S. Geologic Survey topographic maps and two foot contour maps provided by the city of Cadillac were used to extend valley cross-sections.

Hydrology and Hydraulics

Physical data were obtained from U.S.G.S. topographic maps, soil survey maps, local topographic maps and aerial photographs, as well as on-site field inspections. The watershed boundary was determined from map studies and field checks. The watershed was divided into 13 sub-watershed areas for use in evaluating the runoff volumes. Drainage areas for the sub-watersheds were measured from U.S.G.S. topographic maps. Times of concentration were calculated for the sub-watersheds using the upland flow method. Each sub-watershed was evaluated for land use, cover and soils. Runoff curve numbers were calculated.

Due to considerable differences in sub-watersheds, travel times, time of concentrations, soil conditions and topography, the analyses consist of three parts: 1) Lake Mitchell and Lake Cadillac, 2) Clam River and 3) Pleasant Lake.

Lake Mitchell and Lake Cadillac:

The lakes were treated as one body of water. The drainage area above the lakes is approximately 75 square miles; however, the area that contributes surface runoff is only about 46 square miles. The soils are very sandy and pervious with considerable vegetative cover. Many of the roads prevent surface runoff from directly entering the lakes. In addition, several of the smaller lakes and swamps above Lake Mitchell and Lake Cadillac are landlocked. Therefore, a surface water analysis alone would not be adequate. Snowmelt and groundwater needed to be included.

Information from U.S.G.S. stream gage No. 04121300 located at Vogel Center was utilized to develop information for the TR-20 flood routing program used to determine elevations and peak discharges out of the lakes. Inflow hydrographs into the lakes were developed based on a volume-duration-probability analyses of the gage and the area above the lakes. Outflow hydrographs were based on elevation-discharge relationships developed by the WSP-2 water surface profile program and storage calculations. Daily lake elevation records from the U.S.G.S. staff gage located at Lake Cadillac, along with Weather Bureau data, were used to determine a starting lake elevation of 1290.5, which was used to model existing conditions. The TR-20 computer program used the Storage Indication method of evaluating the effect of the lakes in reducing peak flood discharges into the Clam River. Table 1 (Appendix C) lists discharges obtained from the flood routings and Table 2 (Appendix C) lists lake elevations.

Information from the U.S.G.S. staff gage located at Lake Cadillac was used to verify the peak lake elevations. A frequency analysis using a Weibull plot very closely approximates peak elevations as determined by the TR-20 model.

Clam River:

Channel flood routings to establish peak discharge-frequency relationships were made using the SCS TR-20 Hydrology Computer Program and U.S. Department of Agriculture computer facilities. The Modified Attenuation-Kinematic (Att-Kin) method of routing through stream channels is used by this program. This method is derived from inflow-outflow hydrograph relationships.

Base flood flows from Lake Cadillac and Lake Mitchell, local runoff and valley sections were used to flood route and model study area conditions. Table 1 (Appendix C) lists discharges obtained from the flood routings and Table 2 (Appendix C) lists flood elevations at sections.

Information from the U.S.G.S. stream gage at Vogel Center and U.S.G.S. Water Supply Paper 1677 were used to verify peak discharges at the county line as determined by the TR-20 model. Peak discharges for the 100-year flood compared within 4 percent.

Pleasant Lake:

The Pleasant Lake drainage area is approximately 4.25 square miles. Flood waters from Pleasant Lake flow to the south under Road No. 32 and eventually enter Lake Cadillac and Lake Mitchell. The hydrology and hydraulics analysis was similar to Lake Cadillac and Lake Mitchell.

Inflow hydrographs into the lake were developed based on a volume-duration-probability analysis of the U.S.G.S. stream gage at Vogel Center. Outflow hydrographs for discharge out of the lake were based on elevation-discharge relationships developed by the WSP-2 water surface profile program and TR-20 flood routing program. A starting lake elevation of 1326.80 feet was used to model existing conditions. Table 1 (Appendix C) lists discharges obtained from the flood routings and Table 2 (Appendix C) lists lake elevations.

Water surface profiles for the Clam River and Pleasant Lake outlet channel were developed using the Soil Conservation Service WSP-2 computer program. This program uses the step method of computation to solve the Bernoulli equation, and the Bureau of Public Roads bridge loss analysis. Flood discharges determined from flood routings were used in the water surface profile program to develop high water profiles along the Clam River and Pleasant Lake outlet channel. Mannings "n" values were determined from field investigations of the channels and flood plains.

Normal bridge and channel flow conditions were assumed in the hydraulic computations. No consideration was made for openings blocked by ice or other debris. Channel and flood plain flow characteristics may change due to vegetative growth, sedimentation, scour, debris accumulation, filling and encroachment. Computations for this study considered only those features in the flood plain at the time of field surveys. Future flood plain developments and modifications, as well as changes in the upstream drainage area and land use and cover will require recomputation of water surface profiles.

Flood plain delineations were made on the contour maps and photo map sheets. Computed water surface elevations at surveyed sections and bridges were used to identify flood plain limits. Between sections, topographic map interpretations and field inspections were used to delineate the flood boundary lines. Limits of flooding shown on the photo maps may vary from actual location on the ground and the photographic image may vary from true ground location due to inherent aerial photographic displacement. Flood plain delineations around Lake Cadillac and Lake Mitchell were based on the computed lake level. Wave action may cause flooding of additional areas. In addition, road fills with inadequate or no crossings and high water table soils are causing some flooding above the roads. These areas were delineated as flood prone areas in this study. In most cases, these areas are above the 500-year and 100-year flood elevations. Detailed soil borings should be conducted in these areas in the event of possible development. High water profile elevations and detailed field surveys should be used to determine the extent or depth of flooding at any specific site.

Where the limits of the 500-year and 100-year floods were too close to delineate, the limits of the two flood plains are shown as the same line on the flood hazard area sheets.

APPENDIX E





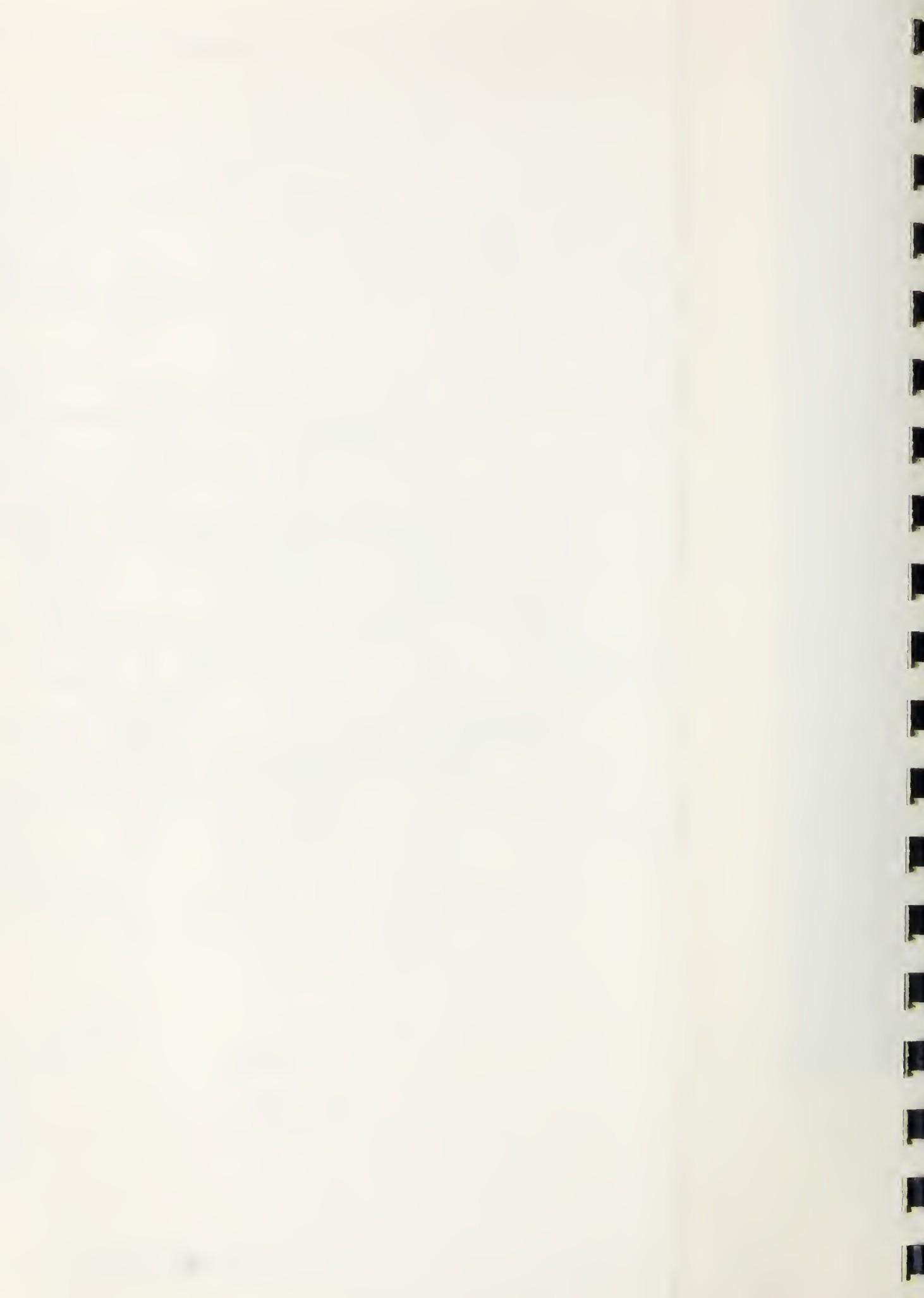
BENCH MARK LOCATION MAP
CLAM RIVER
FLOOD PLAIN MANAGEMENT STUDY
PORTIONS OF
WEXFORD COUNTY, MICHIGAN



VICINITY MAP

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JULY 1987 1000651



BENCH MARK DESCRIPTIONS *

CLAM RIVER

WEXFORD COUNTY, MICHIGAN

BM 70B

Section 24, T22N, R9W - Railroad spike in south side of power pole located 75 feet west of Missaukee County Line Road also known as 49 Road and 80 feet south of the Clam River.

Elev. 1269.27

BM 65B

Section 24, T22N, R9W - Top of iron in concrete marker located 50 feet north-west of the intersection of Boon Road and Sarah Street.

Elev. 1286.06

BM 62B

Section 23, T22N, R9W - Railroad spike in south side of power pole located near section line common to sections 23 and 24. The power pole is the first power pole south of the Clam River.

Elev. 1273.38

BM 60B

Section 23, T22N, R9W - Railroad spike in the north side of power pole located 65 feet northwest of the south 1/16 corner of southeast 1/4 of section 23.

Elev. 1287.14

BM 55B

Section 22, T22N, R9W - Railroad spike in the south side of power pole, located on the north side of Boon Road and being the first power pole west of the Clam River and Boon Road intersection.

Elev. 1283.24

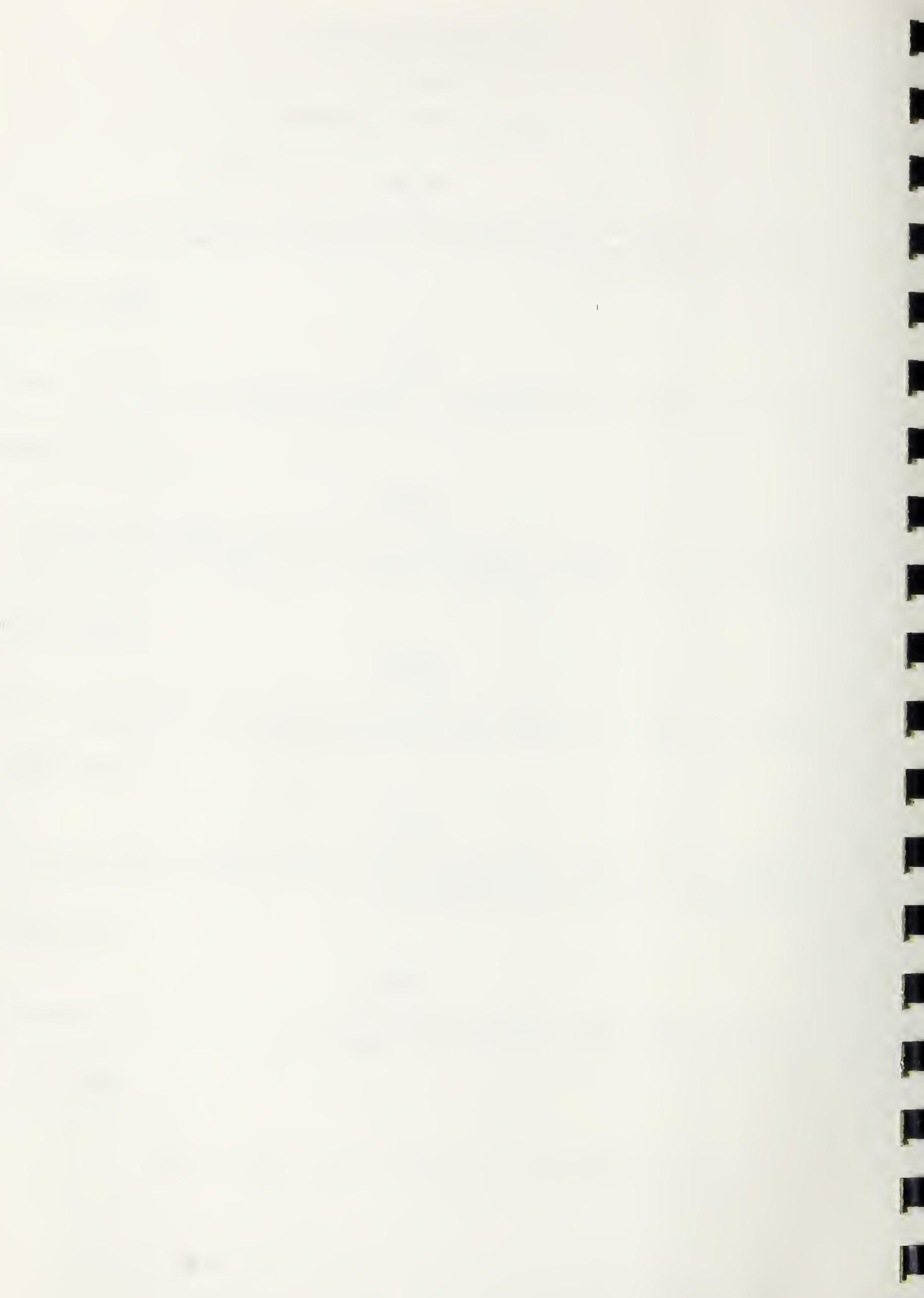
BM 50

Section 27, T22N, R9W - Railroad spike in west side of power pole, southeast of the junction of Boon Road and Plett Road.

Elev. 1285.59

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* Elevations based on USC & GS mean sea level datum of 1929.



BM 42

Section 34, T22N, R9W - Railroad spike in north side of power pole located at the southeast corner of the intersection of Platt Road and 13th Street.

Elev. 1288.63

BM 144

Section 33, T22N, R9W - Railroad spike in power pole at the south side of Ford Street at the intersection of Ford, Dandy and Riverside Street.

Elev. 1289.34

BM 146

Section 33, T22N, R9W - Railroad spike in guy pole at the southwest corner of Ayer and Wheeler Streets.

Elev. 1293.34

BM 73

Section 33, T22N, R9W - Top of steamer valve on fire hydrant located at the northwest corner of Powers and Baker Streets.

Elev. 1291.10

BM 78

Section 33, T22N, R9W - Top of steamer valve on fire hydrant located in the southerly corner of Wheeler Street and North Simmons Street.

Elev. 1294.26

TBM 780B

Section 33, T22N, R9W - Top of the northeast corner of the fourth concrete guardrail pillar to the north located on the east side of U.S. 131 at Giantway.

Elev. 1294.71

BM 140

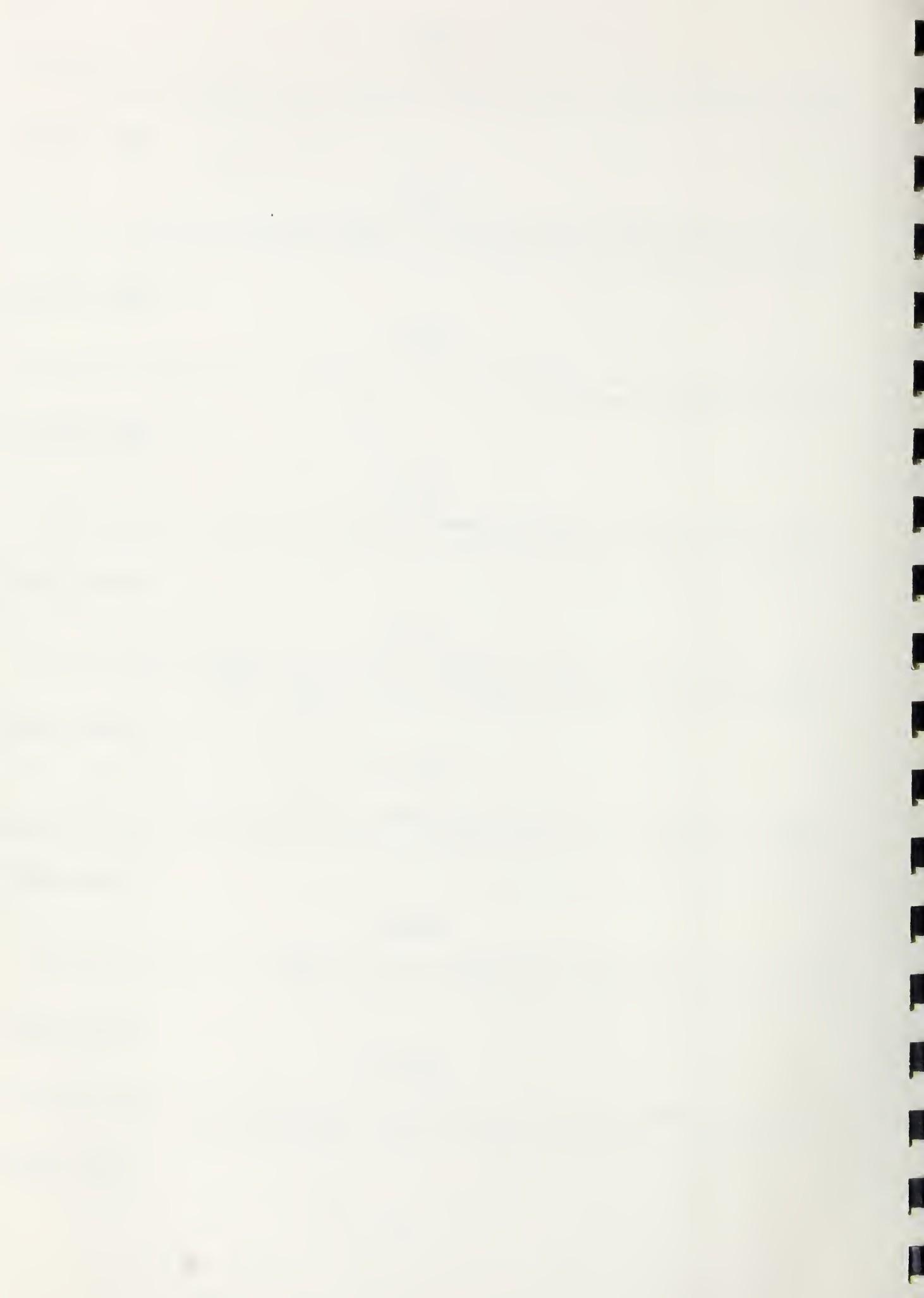
Section 33, T22N, R9W - Chisled mark on top of safety rail at the northwest corner of the Clam River Bridge near Novak Building.

Elev. 1295.12

BM 145B

Section 33, T22N, R9W - Top of steamer valve on fire hydrant located southeast of the corner of West River Street (Wright) and Second Ave.

Elev. 1295.45



TBM 140B

Section 33, T22N, R9W - "X" chisled in top of square steel rod at the north-east corner of Wood Railroad Tressel located in the northwest corner of the Ann Arbor railroad and Clam River intersection. 550 feet southwest of the intersection of Lake Street and West River Street (Wright).

Elev. 1290.75

BM 39

Section 33, T22N, R9W - South bolt on fire hydrant located east of the intersection of Bond and Haynes Street.

Elev. 1294.02

BM DAM

Section 33, T22N, R9W - "X" chiseled on top of southwest corner of concrete abutment of the Clam River Dam at Consumers Power.

Elev. 1292.07

TBM 1-36

Section 1, T21N, R10W - Spike in power pole located in front of House No. 917 North Lake Mitchell Drive.

Elev. 1293.43

TBM 1-39

Section 1, T21N, R10W - Spike in power pole opposite 477 North Lake Mitchell Drive.

Elev. 1294.72

BM 61

Section 6, T21N, R9W - Spike in the west side of power pole located northeast of the intersection of M-115 and North Blvd.

Elev. 1302.34

BM 61B

Section 6, T21N, R9W - Railroad spike in south side of power pole No. 505 located on the north side of North Boulevard 720 feet east of M-115.

Elev. 1293.27

BM 169

Section 7, T21N, R9W - Railroad spike in power pole at the westerly corner of the intersection of M-55 and S. Lake Mitchell Drive of Cadillac West Motel.

Elev. 1296.44

TBM 2-26

Section 12, T21N, R10W - Spike in north root of 20 inch diameter red oak south side of M-55 at Caberfac Motor Inn.

Elev. 1299.96

BM Bl

Section 12, T21N, R10W - Split "l" on top of northeast edge of Bell Systems manhole cover rim located in northerly corner of M-55 and Pole Road Junction.

Elev. 1295.91

TBM 2-15

Section 10, T21N, R10W - Chiseled "X" in top square of triangular concrete post, 15 feet west and 25 feet south of Sunset Pt. Road (33 Mile Road) at the intersection of South Lake Mitchell Drive and 33 Mile Road.

Elev. 1299.40

TBM 2-2

Section 10, T21N, R10W - Spike in east side of 20 inch poplar tree 50 feet south and 25 feet west of the intersection of Sunset Point Road and Woodland Drive.

Elev. 1297.66

BM 220B

Section 10, T21N, R10W - Railroad spike in north side of power pole at the south side and end of 33 Road at Sunset Point Cabins.

Elev. 1293.07

TBM 230B

Section 10, T21N, R10W - Railroad spike in north side of power pole located in the southeast corner of the intersection of South Lake Mitchell Drive (Pole Road) and South 31 Road.

Elev. 1301.25

TBM 231B

Section 9, T21N, R10W - Railroad spike in east side of 12 inch diameter maple tree located on the west side of 31 Road, 0.25 miles north of Pole Road.

Elev. 1297.16

TBM 1-1

Section 3, T21N, R10W - Spike in power pole south of House No. 519 Lake Drive.

Elev. 1295.33

TBM 1-8

Section 34, T22N, R10W - Spike in power pole on south side of North Lake Mitchell Drive at House No. 4301.

Elev. 1294.34

TBM 1-15

Section 35, T22N, R10W - Spike in power pole at west side of House No. 3367 North Lake Mitchell Drive.

Elev. 1292.30

BM B7

Section 26, T22N, R10W - Top of cap on cement marker reading "Wexford County Board of Public Works" located 75 feet east and 50 feet north of the intersection of North Lake Mitchell Drive and Ann Arbor railroad tracks.

Elev. 1296.87

BM B8

Section 25, T22N, R10W - Top northeast corner concrete marker, "Wexford County Board of Public Works", located 45 feet north and 35 feet east of the intersection of East Lake Mitchell Drive and Ann Arbor railroad tracks.

Elev. 1305.93

BM B9

Section 25, T22N, R10W - Top of the northwest bolt of the railroad warning light base, located in the southeast corner of the intersection of M-115 and Ann Arbor railroad tracks.

Elev. 1307.25

BM 13

Section 22, T22N, R10W - 2 miles north and 6 miles west of Cadillac, 27 feet north and 35 feet east of crossroads, 12 feet east of corner post, in concrete post, standard tablet stamped "TT 112 TEX 1930 1353".

Elev. 1353.06

BM LJ 105

Section 14, T22N, R10W - Top of nail set 0.5 feet above ground, south side of power pole, 39 feet north of Rd. No. 32, 419 feet east of the intersection of 35 Rd. and Rd. No. 32 at No. 5095.

Elev. 1335.17

BM LJ 107

Section 13, T22N, R10W - Top of nail set 6 inches up from ground on west side of power pole, east side of Lake Shore Drive and south side of drive to Richardsons at No. 2753 Lake Shore Drive.

Elev. 1331.42

BM LJ 109

Section 13, T22N, R10W - Top of nail set 6 inches up from ground on west side of power pole, 39 feet east of 35 1/2 Road, and 178 feet north of intersection of Lake Shore Drive and 35 1/2 Road.

Elev. 1338.61

APPENDIX F

GLOSSARY

BACKWATER--The resulting highwater surface upstream from a dam, bridge or other obstruction in a river channel or high stages in a receiving stream.

BRIDGE DECK--Elevation of road surface at the bridge.

BRIDGE LOW CLEARANCE--The lowest point of a bridge or other structure over or across a river, stream or water course that limits the opening through which water flows. This is referred to as "low steel" or "low chord". It often is higher than the low point of the roadway.

CHANNEL or WATER COURSE--An elongated depression either natural or man-made having a bed and well-defined banks varying in depth, width and length which gives direction to a current of water and is normally described as a creek, stream or riverbed.

CHANNEL BOTTOM--The lowest part of the stream channel (either in a constructed cross-section or a natural channel). Bottom elevations at a series of points along the length of a stream may be plotted and connected to provide a stream bottom profile.

CONFLUENCE--A flowing together or place of junction of two or more streams.

CROSS-SECTION or VALLEY SECTION--A graph showing the shape of the stream bed, banks and adjacent land on either side made by plotting elevations at measured distances along a line perpendicular to the flow of the stream.

DATUM--An assumed reference plane from which elevations and depths are measured such as from sea level.

ELEVATION-DISCHARGE RELATIONSHIP--The relationship between water surface elevation and rate of flow at a specified location for a range of flow rates.

FLOOD--A temporary overflow by a river, stream, ocean, lake or other body of lands not normally covered by water. It does not include the ponding of surface water due to inadequate drainage such as within a development. It is characterized by damaging inundation, backwater effects of surcharging sewers and local drainage channels, and by unsanitary conditions within adjoining habituated area attributable to pollutants, debris and water table.

FLOOD CREST--The maximum stage or elevation reached by flood waters at a given location.

FLOOD FREQUENCY--A means of expressing the probability of flood occurrences as determined from a statistical analysis of representative stream flow or rainfall and runoff records. It is customary to estimate the frequency with which specific flood stages or discharges may be equaled or exceeded, rather than the frequency of an exact stage or discharge. Such estimates by strict definition are designated "exceedence frequency", but in practice the term "frequency" is used. The frequency of a particular stage or discharge is usually expressed as occurring once in a specified number of years.

10-YEAR FLOOD--A flood having a long-term average frequency of occurrence in the order of once in 10 years. It has a ten percent chance of being equaled or exceeded in any given year.

100-YEAR FLOOD--A flood having a long-term average frequency of occurrence in the order of once in 100 years. It has a one percent chance of being equaled or exceeded in any given year. This flood is comparable to the "Intermediate Regional Flood" used by the U.S. Army Corps of Engineers.

FLOOD PEAK--The maximum instantaneous discharge or volume of flow in cubic feet per second passing a given location. It usually occurs at or near the time of the flood crest.

FLOOD PLAIN--The relatively flat area or low lands covered by flood waters originating with either the adjoining channel of a water course such as a river or stream, or a body of standing water such as an ocean or lake.

FLOOD PRONE AREA--Areas that experience ponding due to high water table soils and/or inadequate outlets.

FLOOD ROUTING--The process of determining progressively the timing and shape of a flood wave at successive points along a stream. This procedure is used to derive a downstream hydrograph from an upstream hydrograph. Local inflow and tributary hydrographs are considered.

FLOOD STAGE--The elevation at which overflow of the natural stream banks or body of water occurs.

FLOODWAY--The portion of the flood plain including the channel of the stream that is required for the conveyance of flood flow.

FLOODWAY FRINGE--The area of the flood plain lying outside the floodway which may be covered by flood waters originating from an adjoining river or stream.

HEAD LOSS--The effect of obstructions, such as narrow bridge openings, dams or buildings, that limit the area through which water must flow, raising the surface water upstream from the obstruction.

HEADWATER--The tributaries and upper reaches which are the sources of the stream.

HIGH WATER or FLOOD PROFILE--A graph showing the relationship of water surface elevation location along the stream. While it is drawn to show surface elevations for the crest of a specific flood, it may be prepared for conditions at any other given time or stage.

HYDRAULICS--The science of the laws governing the motion of water and their practical applications.

HYDROGRAPH--A graph denoting the discharge or stage of flow over a period of time.

HYDROLOGY--The science dealing with the occurrence and movement of water upon and beneath the land areas of the earth.

INUNDATION--The flooding or overflow of an area with water.

LEFT BANK--The bank of the left side of a river, stream or water course, looking downstream.

LOW GROUND--The highest elevation at a specific stream channel cross-section at which the flow in the stream can be contained in the channel without over-flowing into adjacent overbank areas.

MANNING'S "n"--A coefficient of channel and overbank roughness used in Manning's open channel flow formula, commonly called a retardance factor.

REACH LENGTH--A longitudinal length of stream channel selected for use in hydraulic or other computations.

RIGHT BANK--The bank on the right side of the river, stream or water course, looking downstream.

ROAD OVERFLOW--The lowest elevation on a road profile in the vicinity of where the road and stream cross. It is the first point on the roadway inundated if overtopping of the road occurs during a storm.

RUNOFF--That part of precipitation, as well as any other flow contributions, which appears in surface streams of either perennial or intermittent form.

TIME OF CONCENTRATION--Time required for water to flow from the most remote point of a watershed to the outlet or other point of reference.

WATERSHED--A drainage basin or area which collects runoff and transmits it, usually by means of streams and tributaries, to the outlet of the basin.

WATERSHED BOUNDARY--The divide separating one drainage basin from another.

APPENDIX G

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